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Volume 1

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Editors
Anming Zhang
Brent D. Bowen

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University of Nebraska at Omaha

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International Conference on Air Transportation Operations and Policy
City University of Hong Kong
June 6-8, 1999

The Conference

The ATRG held its 3rd Annual Conference at the City University of Hong Kong Campus in June 1999.

The 1999 Conference contained 13 aviation and airport sessions. Over 40 research presentations were featured on topics pertaining to airports and aviation, these titles are listed on the ATRG website (http.//www.commerce.ubc.ca/atrg/).

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DR. ANMING ZHANG, the Acting Head of the Department of Economics and Finance at City University of Hong Kong, joined the City as an associate professor in 1996 after teaching at University of Victoria, Canada, for six years. He received a BSc from Shanghai Jiao Tong University, MSc and PhD (1990, Economics and Business Admin.) from University of British Columbia. Dr. Zhang has published more than 20 research papers in the areas of industrial organization, international trade, and transportation. He received the Yokohama Special Prize for an Outstanding Young Researcher, awarded at the 7th World Conference on Transportation Research (WCTR), Sydney, Australia, July 1995. He won again the Overall Best Paper award (with Tae Oum and Yimin Zhang) at the 8th WCTR, Antwerp, Belgium, July 1998. Dr. Zhang has also done extensive consultancy work for government and industry.

DR. BRENT D. BOWEN is Director and Professor, Aviation Institute, University of Nebraska at Omaha. He has been appointed as a Graduate Faculty of the University of Nebraska System-wide Graduate College. Bowen attained his Doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor, Advanced-Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment in collegiate aviation programs. He is also well published in areas related to effective teaching. His professional affiliations include the University Aviation Association, Council on Aviation Accreditation, World Aerospace Education Organization, International Air Transportation Research Group, Aerospace Education Association, Alpha Eta Rho International Aviation Fraternity, and the Nebraska Academy of Sciences. He also serves as program director and principal investigator of the National Aeronautics and Space Administration funded Nebraska Space Grant and EPSCoR Programs.

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ATRG President's Foreword

The **Air Transport Research Group** of the WCTR Society was formally launched as a special interest group at the 7th Triennial WCTR in Sydney, Australia in 1995. Since then, our membership base has expanded rapidly, and includes nearly 600 active transportation researchers, policy-makers, industry executives, major corporations and research institutes from 28 countries. Our broad base of membership and their strong enthusiasm have pushed the group forward, to continuously initiate new events and projects which will benefit aviation industry and research communities worldwide.

It became a tradition that the ATRG holds an international conference at least once per year . As you know, the 1997 conference was held in Vancouver, Canada. Over 90 papers, panel discussions and invited speeches were presented. In 1998, the ATRG organized a consecutive stream of 14 aviation sessions at the 8th Triennial WCTR Conference (July 12-17: Antwerp). Again, on 19-21 July, 1998, the ATRG Symposium was organized and executed every successfully by Dr. Aisling Reynolds-Feighan of the University College of Dublin.

In 1999, the City University of Hong Kong has hosted the 3rd Annual ATRG Conference. Despite the delay in starting our conference sessions because of Typhoon Maggie, we were able to complete the two-day conference sessions and presentation of all of the papers. On behalf of the ATRG membership, I would like to thank Dr. Anming Zhang who organized the conference and his associates and assistants for their effort which were essential for the success of the conference. Our special thanks go to Professor Richard Ho, Dean of the School of Business and Economics of the University for the generous support for the conference. Many of us also enjoyed the technical visit to the new Hong Kong International Airport (Chep Lok Kok).

As you know, Professor Jaap de Wit and I look forward to welcoming you to University of Amsterdam on July 2-4, 2000 for the 4th Annual ATRG Conference.

As in the past, the Aviation Institute of the University of Nebraska at Omaha (Dr. Brent Bowen , Director of the Institute) has kindly agreed to publish the Proceedings of the 1999 ATRG Hong Kong Conference (being co-edited by Dr. Anming Zhang and Professor Brent Bowen). On behalf of the ATRG members, I would like to express my sincere appreciation to Professor Brent Bowen, Mary M. Schaffart and the staff of the Aviation Institute of University of Nebraska at Omaha for the effort to publish these ATRG proceedings. Also, I would like to thank and congratulate all authors of the papers for their fine contribution to the conferences and the Proceedings. Our special thanks are extended to Boeing Commercial Aviation – Marketing Group for the partial support for publication of this proceedings.

Finally, I would like to draw your attention to the ATRG newsletter and the ATRG website (www.commerce.ubc.ca/atrg/) which will keep you informed of the ATRG operations and forthcoming events. On behalf of the ATRG Networking Committee, I would appreciate it very much if you could suggest others to sign up the ATRG membership. Thank you for your attention.

Tae H. Oum
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Implementation of Satellite-based Systems for Civil Aviation in the 21st Century

The New Airport

Before going into the subject of satellite systems I would like to say a few words about the new Hong Kong International Airport at Chek Lap Kok. Since opening, the airport has won several awards of excellence from world renowned organizations and is now operating as a world class airport processing a large number of passengers and aircraft during the peak season.

The airport is constructed on reclaimed land and has an area of 1,248 hectares. It has two runways which are 3,800 metres long and 69 metres wide, capable of supporting ultra long haul flights. The south runway has been in operation since opening on 6 July 1998 and the north runway is now being used during peak traffic period between 1000 and 1600 hours daily and will be brought into full operation in August this year. The south runway is equipped with Category II Instrument Landing System (ILS) on both ends and the north runway is equipped with Category IIIA ILS for approach from the northeast and Category II from the southwest.

Air Traffic Control Equipment

In order to support the operation of the new airport, some 20 items of air traffic control equipment have been purchased and installed. These

include new navigation beacons installed in the vicinity of the airport (at Lung Kwu Chau and Siu Mo To) to support instrument flight procedures, new radars installed at Sha Chau and Tai Mo Shan to improve the coverage at the new airport and in the Pearl River Delta. Surface Movement Radar (SMR) for ground surveillance at the airport and to detect aircraft and vehicles on the airfield; and new communications equipment to increase channel capacity in two-way voice communication with aircraft.

In the Air Traffic Control Complex and Control Tower at the middle of the airfield, computerized Radar Data Processing and Display System (RDPDS), Flight Data Processing System (FDPS), Aeronautical Information Data Base (AIDB) and Automatic Message Switching System (AMSS) are installed to provide air traffic control service to aircraft operating within Hong Kong airspace and communication services to airlines operators, overseas airports and neighbouring air traffic control centres. The new RDPDS is also equipped with some of the new Air Traffic Management (ATM) functions such as conflict alert and minimum safe altitude warning (MSAW). With these new features, flight safety is greatly enhanced.

Transition to Satellite-based Systems

The existing ATC systems rely mainly on ground-based radar, navigation aids and communications equipment which have a number of limitations, for example, limited coverage (mainly due to line-of-sight coverage of VHF, UHF, etc), their susceptibility to the effects of adverse weather, the lack of digital data transfer capability between aircraft in the air and air traffic control units on the ground.

In the early 1980's, it became evident to International Civil Aviation Organization (ICAO) that the present ground-based ATC system would not be adequate to meet the demand and operation into the 21st century. As a consequence, a Special Committee on Future Air Navigation System (FANS) was established in 1983 to study, identify and assess new technologies as well as to make recommendations for the future development of air navigation systems for civil aviation.

The systems developed by the FANS Committee are known as the satellite-based Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) systems. The function of the various systems are described below.

Communications

This initiative mainly involves the introduction of data relay and voice communications using satellite platforms. Currently, these forms of communications are readily available in the commercial sector. In some newer type of aircraft, Satellite Communication (SATCOM) is already available to the passengers and Aircraft Communication Addressing and Reporting System (ACARS) available to the flight crew.

The regular use of digital data communications, as opposed to voice communications under the existing system, will offer new opportunities for improving the speed and accuracy in the dissemination and receipt of aeronautical information amongst different aeronautical authorities, aircraft in flight and airline operation centres, thus enhancing efficiency. The major components include Satellite Voice Network, Controller-Pilot Data Link Communication (CPDLC), High Frequency (HF) or Very High Frequency (VHF) Data Links, Aeronautical Telecommunication Network (ATN) and Air Traffic Services Inter-facility Data Communication (AIDC).

Navigation

This initiative involves the use of signals from a set of satellites as opposed to the existing ground-based systems for navigation, and making approaches/landing. Global Positioning System (GPS) which is widely used for position fixing is a good example. New systems being developed are the Global Navigation Satellite System (GNSS), Wide Area Augmentation System (WASS) and Local Area Augmentation System (LAAS). The new systems will provide a high-integrity, high-accuracy and all-weather navigation services. With suitable upgrade, they would be able to support precision landing by aircraft.

Surveillance

This initiative involves multiple efforts to improve the surveillance of aircraft. The existing radar systems have a range limitation of about 250NM. The Automatic Dependent Surveillance (ADS) can be employed to automatically and continuously track the aircraft's position, heading and speed and display such information to the controller via satellite or VHF/HF links. The real time information received will permit the controller to exercise positive control of air traffic, particularly in areas outside radar coverage. Within the busy airspace in the vicinity of the airport, Mode S radar (which provides the capability of individual addressing, thereby facilitating aircraft identification) will be introduced to supplement the traditional Secondary Surveillance Radar (SSR). Furthermore, Enhanced Ground Movement Control System (EGMCS) will be provided to allow more positive and accurate surveillance of moving targets such as aircraft, vehicles on the airfield.

Air Traffic Management (ATM)

This initiative consists of new ways of providing air traffic services, e.g. the use of air traffic flow management to regulate traffic flow and the provision of safety related features such as conflict predication and alert, minimum safe altitude warning (MSAW), arrival metering, sequencing and spacing, and trajectory conformance monitoring, etc. The aim is to provide an integrated ATM system in a regional or global context which would permit aircraft operators to conduct flights in accordance with their preferred route and to make dynamic adjustment of flight profile in accordance with weather conditions encountered en route, thus permitting flight operations in the most optimum and cost-efficient manner.

Benefits of the CNS/ATM Systems

The CNS/ATM systems will tremendously improve the handling and transfer of updated information such as weather, aeronautical information, status of aircraft and ATC messages between aircraft and the ATC centres. They will also extend surveillance coverage beyond the normal limit and improve navigational accuracy. As a result of the new initiatives, reduction of separation between aircraft and increased capacity will be

achieved. The advanced ATC Automation System will exchange data directly with aircraft through data link. This will enable improved conflict detection through intelligent processing, provision for the automatic generation and transmission of ATC clearances for conflict resolution as well as offering a new environment for operation of "free flights".

In summary, the direct and indirect benefits of the CNS/ATM systems include enhancement of flight safety, increase in airspace capacity, savings in flight time and fuel, as well as reduction in disruption to air services arising from adverse weather.

Implementation of CNS/ATM Systems

On the international front, the first Global Implementation Plan for the satellite-based CNS/ATM systems was developed by ICAO in 1993 and subsequently updated. All Contracting States, including China, are required to comply with the Plan. At the same time, the Asia Pacific Economic Co-operation (APEC) has also established a Satellite Navigation and Communication (SN&C) Systems Advisory Committee to monitor and co-ordinate, in conjunction with the ICAO Regional Office and various APEC Economies, the implementation of such systems within the APEC region.

Many countries have commenced study, operational trial and evaluation of the CNS/ATM elements with a view to complying with the Global Implementation Plan and launching services of the new CNS/ATM systems for use by airlines at an early date. In this regard, U.S.A., Japan, Singapore and the Mainland have started the design and trail of at least five elements of the CNS/ATM systems.

Many of the newer generation aircraft are now FANS equipped. The exploration of new FANS routes to North America to shorten the flying time has also been one of the major development in the Asia Pacific region. Over the years, the North Pacific Flexi Routes have been heavily utilized. However, with the opening of the Russian Far East airspace, more new routes are now available. Examples are the FANS route to Chicago and the Polar route to New York.

CAD commenced preliminary planning and investigation on some of the CNS/ATM systems since 1992. Initial trail on two elements of the system, i.e. ADS and CPDLC, has started in June 1994. The results have been satisfactory. To maintain the competitive edge of Hong Kong in the civil aviation field, CAD has worked out a 3-phase CNS/ATM Implementation Plan.

Conclusion

Hong Kong's New Airport has excellent facilities and plenty of potential for development, and highly capable of supporting traffic growth well into the 21st century. In addition, we are also committed to implementing the CNS/ATM systems in order to provide a safer and more efficient air traffic control system to cope with the future demand. With the new facilities available, we are confident that we shall be able to maintain Hong Kong as a centre of regional and international civil aviation. Thank you.

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Prospects of the Air Transport Industry in China

(Air Transport Research Group Conference – Hong Kong SAR, China 1999, by Peter Lok, Secretary General, China (HK) International Aerospace Forum)

Dr Anming Zhang very kindly allowed me a preview of one of his masterpieces, the very thought-provoking paper "Prospect of Air Transport Industry and Strategies for Open Skies in China" co-authored with Hongmin Chen. This paper is in my view a very methodic and penetrating analysis of what has happened in the two decades of "gaige-kaifang" (reform and opening up) since 1979 in the very demanding industry of Air Transport. It is thought-provoking against the background of China, a country which, because of its deep-rooted intuitive cultural background, continued to adopt a not very methodic approach towards any industry. From this inevitably retrospective analysis with an understandably academic bias, the paper proceeds to project demand growth on the basis of projected economic growth, and to theorise on the prospects of an open-skies policy being adopted in China. I am sure we all share the dilemma that on the one hand, one has to look ahead over a period of at least 10 - 15 years in order to make a meaningful projection for investment purposes, and yet on the other hand, so many unforeseeable things could happen in a much shorter time which would make those projections woefully wrong. And remember what Disraeli said, "lies, damned lies and statistics".

The subject matter strikes a chord with me because I had a part in resurrecting the very, very important air transport link between the Mainland and the then British administered Hong Kong, as soon as "gaige-kaifang" started in 1979. That link had by then been severed for three decades because of the East-West ideological struggle, the Cold War, punctuated by the Korean War and the Vietnam War in this part of the world. For my part, I will attempt to fill in some views taken from a less methodic and academic but more intuitive and slightly more industry oriented angle, to speculate on the effect of the more philosophical factors on the development of the air transport industry in China. I say "slightly more industry oriented angle" because my working life has been spent substantially on the regulatory side and barely at the "receiving end", on the regulated side.

Asia is in the middle of an economic crisis. In Chinese the term for crisis translates into "danger and opportunities". By pointing out the dangers in the industry, we are also pointing out the opportunities.

Lest you should think I am indulging in a one-sided criticism of the Mainland air transport industry, and the regulation thereof, let me hasten to add that Motherland's air transport industry. like everything else including the much maligned human-rights track record, has come a long long way since the start of "gaige-kaifang" just a short 20 years ago. Twenty years is barely the blink of an eye in the long history of this longest continuing civilisation. From being a means of transport for senior government officials, aviation has evolved into a very useable means of public transport in that very short time. (You should have seen Guangzhou where the air service resumption talks were held, in 1979. There were hardly any motor vehicles in sight. The only means of travel to from the Guangzhou Trade Fair was via Hong Kong by the very infrequent

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KCR train or the slow steam-boat type ferries neither of which could give you a trip to Guangzhou and to return the same day to the creature comforts of Hong Kong. Look what it is now, just 20 years later! You could squeeze in a few hours of business in Guangzhou and return to Hong Kong the same day, by coach, train, fast ferry or by air. By air, you could do that even to Shanghai and to Beijing. Every Mainland provincial capital is now served by air from the Hong Kong SAR.)

Although supposedly the previously two-in-one CAAC has been separated into a **regulatory** authority called CAAC on the one hand and the **regulated** enterprise in the form of the six major airlines on the other, in reality these airlines in the majority are still the national assets of the CAAC. CAAC in conjunction with CASC through the Planning Commission still calls the shots on what aircraft types to buy in bulk. CAAC continues to dictate how many of the aircraft bought are to be allocated to which of the six airlines, which of the six airlines are to be designated on which international routes under the bilateral air services agreements and what profit-and-loss targets they must budget for. Managers in the airlines and administrators in CAAC continue to swap position.

Rigid and outdated operating practices continue to be decreed by CAAC to the airlines. For example, Flight Plans continue to be computed on the basis of the worst meteorological conditions of the year at destination, resulting routinely in over-fuelling of the aircraft for the journey, hence higher than necessary fuel burn in carrying that excess fuel, and a consequent reduction in payload, costing the airlines country-wide millions of (US) dollars a year (Matt Chen of AMR). On a trans-Pacific westbound cargo flight, struggling against the eternal headwind, instead of picking up the maximum payload cargo and planning for a refuelling stop at an intermediate point, which the cargo will not complain of, a Chinese airline freighter would instead uplift maximum fuel and sacrifice some lucrative cargo payload. Meantime the counterpart American airlines would be screaming for flight frequency increase to meet market demand, but the Chinese airlines would want to reduce frequency! In such imbalance of operating efficiency and operating economics, an open-skies policy, if adopted, would obviously not work in the Chinese airline's favour. Meantime, the exporting and cargo forwarding industries are stifled. Meantime a new US – China air service bilateral was concluded in April during Premier Zhu Rongji's visit to the US which will see capacity doubled in 3 years.

Ridiculous rules continue to govern whether and what food the passengers should be served For example, if your flight departs after the lunch or supper time that is normal in China, you are not served a meal, in some cases no food at all but ironically some appetising drinks! They forget that you would not have had the chance to take your meal while travelling to the airport to check in.

While the country continues to suffer shortage of airspace capacity, the military authorities continue to "own" the country's airspace. from earth all the way to heaven The much needed short-range commuter air services between the Hong Kong SAR and South China for instance simply cannot get started without then say-so My conservative estimate is that there are close to 30 million passenge trips made by land and sea transports between the SAR and South China Yet there are only 4 points in the Guangdong province that are

served by air direct from the SAR. If only 0.5% of that surface transport traffic converts to air travel, that translates into a very sizeable market demand.

Air traffic control (ATC) continues to apply procedural separation standards, although at least in the Beijing-Guangzhou-Hong Kong-Shanghai corridors already released to civilian control from the military, continuous radar coverage has been achieved. If only ATC will cease to insist on 10 minutes between successive flights regardless of cruising levels, the airspace capacity will be raised by 50% or more. But who will risk his neck to do away with the well entrenched procedural method? Without doing so, how will the projected three-fold demand be served?

While the airlines suffered in 1998 over-capacity and low load factors, the attempt has ironically been to dispose of small-capacity aircraft types which could be usefully deployed to mount more frequent and so more convenient services to attract more travellers. Services have been cancelled without prior notice and the hapless passengers already checked in and trapped on the airside of the airport are herded onto a later flight using a large-capacity aircraft type.

Some departments of airlines are well, well over-staffed, with ex-military personnel implanted for good relations. I cannot see how so many mouths can be fed with such low-efficiency operations.

Not surprisingly China Southern and China Eastern Airlines posted a loss of several hundred million RMB in 1998.

The airports? Strangely, the farther they are from the power base Beijing, the better they are run and the revenue sources therein better exploited. Just look at the Beijing Capital Airport. What enormous commercial potentials remain untapped in the terminal building and how indifferent the services to passengers are? Could it be that the there are no incentives (carrots) to do better and the employees are all somebody's somebody so that penalties (big sticks) cannot be easily meted out? Or is it because its ownership and responsibility for operational efficiency and profit & loss have not yet been transferred to local municipal authorities, unlike Xiamen and Shanghai Hongqiao? Shanghai is in a quandary as to which of the existing airlines' operations are to be moved to or shared with the new Pudong Airport to be opened this year. I am sure Tokyo Narita and Haneda are being closely consulted. One reason for being reluctant to shut down Hongqiao is that Pudong will not have the capacity on opening to take over Hongqiao's operations completely. The other reason is to ensure against Pudong not being quite ready then and to avoid the airport opening fiasco which Hong Kong suffered in July 1998. And why cannot the Capital Airport be transferred to the Beijing municipal authorities? For security reasons? What is the solution? Some 60% of the airport revenue at the Hong Kong International Airport is derived from the commercial source, the rest from the aeronautical source such as landing and parking charges and air navigation charges. What are the respective percentages for the Capital Airport?

And why is air cargo hauled hundreds of miles by land from the Mainland to the Hong Kong SAR to be flown out? About 70% of the outbound air cargo flown out from Hong Kong originated from the Mainland. Too much red tape at

Mainland airports is one reason. The other reason, and a diminishing reason as more international air routes are opened up from the Mainland, is that Hong Kong has a very comprehensive network of air routes and high frequencies of flights to the export markets. Frequencies not of the freighter aircraft, which constitute only about 10% of the total aircraft movements, but of the wide-bodied passenger aircraft. The B747 passenger aircraft can carry about 15 tonnes of cargo in its belly hold, and the newer big twin-engine passenger aircraft types, with no body gears to take up belly hold space, can carry over 25 tonnes each. That is why over 55% of the air cargo is borne by passenger aircraft there.

Turning to the Mainland aircraft manufacturing industry, it has an enormous workforce on the pay roll for very few civilian hardwares produced and sold. Military hardwares have managed to find good domestic and overseas markets, but with the exception of the FBC-1, and only the airframe of it, all are licensed copies and developments of foreign designs. The industry continues to wax lyrical about the Y-7 turboprop transport. Yet the domestic travellers' mindset is that anything which has a propeller is second-rate, steam-age stuff. The airlines also are reluctant to use the Y-7 partly because of this travellers' mentality, partly the agedness of the design (AN-24) requiring too much maintenance time per flight time, partly the short MTBO of the engines, partly the relatively low despatch reliability, and surprisingly the flight crew themselves looking down on small and propeller-driven machines. The Y-7 is used often as a training machine to transition to the turbine fleet. Apart from the Y-12, which is selling quite well, I cannot think of an indigenous and original design. Even there, the airframe smacks too much of the Otter and the Islander, and the engine is not indigenous. Only in recent months have I seen an indigenous turboprop engine being test run. Although it has the same back-to-front layout of the PT-6, it has all-axial compressor stages, unlike the PT-6. The helicopter scene is less mirky; it simply went all-out to licence manufacture advanced foreign airframe and engine designs, with some considerable success in domestic application.

The common problem between the air transport operating and manufacturing industries appears to be the same as in other industries in China: the ubiquitous over-population, the intuitive approach, the ready acceptance of mediocrity, the reluctance to exercise initiative, and the over-secure social system. The fewer new ideas one proposes, the less the chance of being blamed if it did not work out and so denting one's "iron rice bowl", and vice versa.

At least, however, the legislation through which the industry has to be regulated is coming together at long last, the CCARs. modelled on the US FARs, so that the industry need no longer be regulated by personal whims. Notice that I said "need". The main problem in the Chinese society, and I am one of them, is that sometimes there are no laws available to be applied. At other times when there are such laws they are not applied.

In my opinion the continued "backwardness" of the Mainland air transport industry, like any other modern industries in China but probably more so, has to do with our cultural background, and above all, the centuries old problem of over-population aggravated by low work productivity. There is consequently

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EVALUATION OF AIRLINE ALLIANCE IN INTERNATIONAL AVIATION MARKET USING EQUILIBRIUM ANALYSIS

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1. INTRODUCTION

In the international aviation industry, the level of service such as the number of firms, frequencies and cities which could be served are arranged by bilateral agreement, therefore it is said that the industry is strongly regulated. The U.S. has intended to promote the "open sky policies" which is almost same, in terms of liberalization for the industry, as the deregulation in the U.S. domestic aviation industry. It is thought that the new bilateral agreement between Japan and the U.S. concluded in 1998 improve the level of service significantly in Japan. With this agreement, the market has taken a step toward liberalization of market.

The recent trend of the aviation industry is to build worldwide alliance. Figure 1 shows the current situation of airline alliance. The size of circle indicates the number of passengers carried by the corresponding airline, and the patterns of circle indicate the alliance groups. Most major airlines in the world are included in any of the alliance groups. That is, alliance is one of the most important strategies to survive in this industry.

It is thought that alliance increases not only airline profit but also user benefit. As the results of competition among allied groups, some regions would suffer from decreasing the level of service That is, alliance is one of the factors to change the market structure. Therefore, the effect of alliance is examined and the influence of alliance on the market is also investigated through market equilibrium analysis.
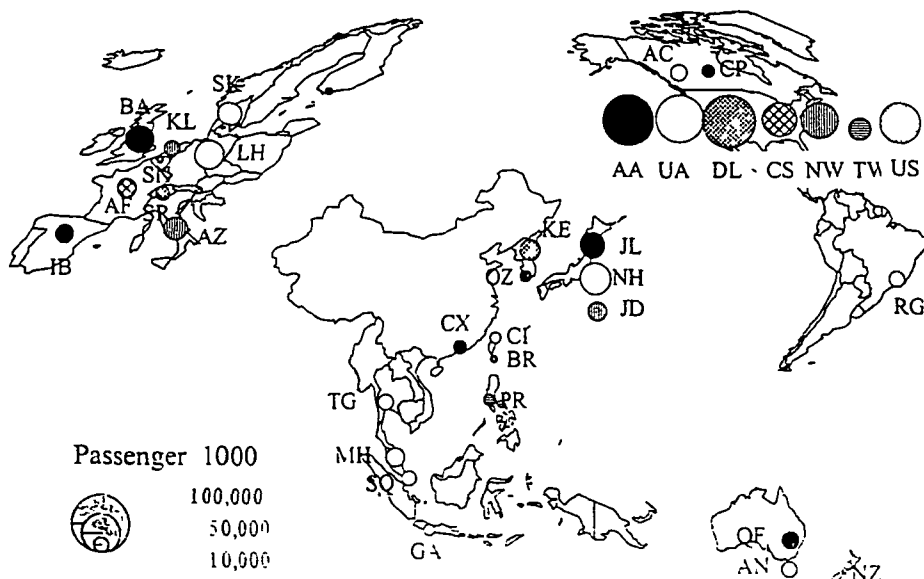
Figure 1 Current Situation of Airline Alliance

just not enough for everyone. Often one has to resort to unfair practices to make ends meet. The way to break out of this vicious circle is to use incentives to increase work ingenuity and productivity, so that there will be enough for everybody. The current economic downturn accentuated these problems.

In the present circumstances, the air transport industry in Mainland China would not stand a chance under the free-competition rules of open-skies, not even under a less liberal Bermuda I or Bermuda II regime, nor experimenting on a limited scale against the Hong Kong SAR in the first instance. So, the Mainland authorities are not about to adopt an open-skies policy in the medium term. No more than the former Hong Kong British administration warmed to the concept of open skies. The US saw more advantages in it because its airlines were already much more efficient than their European counterparts, as did Singapore. To Mainland China the advantages of benefiting the economy as a whole and improving the competitiveness of its airlines will not outweigh the disadvantages. The disadvantages include the short-term demise of its airlines in the manner that the major US airlines like PanAm and Braniff fell by the wayside, or the likes of Continental sought Chapter 11 protection, after the 1978 deregulation exercise. Maybe in light of the China – US trade imbalance China has had to make some concessions in bilateral air service.

Thank you for bearing with my political diatribe.

<div align="center">END</div>

2. REVIEW OF RELATED PAPERS

The papers related to merger and alliance in aviation market should be reviewed in terms of the factors which might cause the change of aviation market structure. After the deregulation of domestic aviation market in the U.S., the number of firms had increased and the condition of domestic aviation market looks like competitive. After the mid-80s, large airline developed new market strategies such as CRS, FFP and Hub and spoke system. Therefore, they could prevent new entrant and form a merger with many small airlines. Then, many studies analyzed the relation between airport dominance and the degree of market competition. It was cleared that market concentration brings high yields. However, S.Morrison et al.[1] pointed out that the term of analysis in the previous studies was not enough long to conclude general view and they also showed a decrease of fare level with long term observation.

Moreover J.A.Glougherty[2] analyzed the influence of merger among domestic airlines on the international aviation market, and it was indicated that the increase of market concentration in the domestic market contributed to increase market share in the international market.

After 1990, the influence of new entrants such as southwest airlines to a niche markets, which remained in hub and spoke networks of mage airlines. And it is founded that an entrant of low cost airline contributes to increase of user benefit owing to decrease of market fare level [3].

Meanwhile, W. Youssef [4] started a research on the airline alliance. The influence of alliance, in terms of changes in level of service, between SR and SAS was investigated. And W.Youssef et al.[5] indicated that alliances cause the network restructuring and that the effect of alliance is explained with density of network, degree of vertical integration and scale of allied firms. GRA[6] demonstrated the effect of code share flights of NW and KL, and US-Air and BA. It was shown that NW and KL increased the traffic and revenue and that US-Air and BA increased traffic with transit by 60%. Moreover, T.F.Hannegan et al.[7], A.Bissessur et al.[8] analyzed the influence of international airline alliance qualitatively, and S.Bayhoff[9] and T.H.Oum ae al.[10] explained the effects of alliance

In recent years, the influence of alliance is examined quantitatively. T.H.,Oum et al.[11] examined the output level of the allied airlines, and it was shown that alliance without market leader makes market leader more competitive. J.H.Park et al.[12] verified the influence of four major alliance in the north Atlantic market by change in quality of service and change of traffic volume. Moreover, J.H.Park et al.[13] defined two types of alliance as parallel alliance and complementary alliance by network structure of allied airlines. And economic models for these two forms of alliance are formulated. Thorough the equilibrium analysis, it was shown that airline profit and user benefit differ by what network is formed after alliance occurs.

The user's preference for service is not considered sufficiently in these papers reviewed above In this paper, service choice models which were estimated in our former research[14] is applied to the behavior passenger. Then, the behaviors of airline and passenger are formulized in chapter 3. And the effects of airline alliance are examined through equilibrium analysis in chapter 4. Finally, under the more realistic market condition, the influence of alliance is examined with considering the heterogeneity of airlines and passengers in chapter 5.

3. FORMULA OF AVIATION MARKET

3.1 Behavior of Air Passenger

A passenger first chooses where to go and then which air route to use This choice structure is

shown in studies of Harvey[15] and Furuichi et al.[16]. In this paper, the nested logit model is adopted to express the choice behavior. When a passenger who lives in region n chooses destination k and an air route r, the probability of that passenger choosing the air route r to the destination k is represented in the lower nests of the nested logit structure by:

$$P_{n(r|k)} = \frac{\exp\left(\ _1V_{(r|k)n}\right)}{\sum_{r'}^{Rkn}\exp\left(\ _1V_{(r'|k)n}\right)}$$ (1)

The marginal probability that a passenger departing from n will choose destination k is represented in the upper nest of the nested logit structure by:

$$P_{n(k)} = \frac{\exp\left(\ _2(V_{kn}+V^*_{kn})\right)}{\sum_{k'}^{Km}\exp\left(\ _2(V_{k'n}+V^*_{k'n})\right)}$$ (2)

$$V^*_{kn} = \frac{1}{_1}\ln\sum_{r}^{R}\exp\left(\ _1V_{(r|k)n}\right)$$ (3)

$$U_{rkn} = V_{(r|k)n} + V_{kn} + \ _{(r|k)n} + \ _{kn}$$ (4)

where

rkn : number of alternative routes for passengers departing from n to destination k;

kn : number of alternative destinations for the passenger departing from n;

U_{rkn} : utility for passengers departing from n to destination k and using route r;

$V_{(r|k)n}$: remaining systematic component of utility specific to combination (r, k);

V_{kn} : systematic component of utility associated with destination k;

$_{(r|k)n}$: random utility component specific to combination (r, k);

$_{kn}$: random utility component specific to destination k;

V^*_{kn} : log sum variables representing maximum expected value of all route r from origin n to destination k;

λ_1 : scale parameter associated with the similarity among alternatives of route r;

λ_2 : scale parameter associated with the similarity among alternatives of destination k.

Then,

$$T^r_{nk} = T_{nk} \cdot P_{n(r|k)}$$ (5)

$$T^r_i = \delta_1^r T^r_{nk} \quad \text{for } i \in I \quad \delta_1^r \begin{cases} 1 & \text{if the route } r \text{ is operated by airline}(i) \\ 0 & \text{otherwise} \end{cases}$$ (6)

$$T^l_i = \sum_r^R \delta_2^r T^r_i \quad \text{for } i \in I \quad \delta_2^r \begin{cases} 1 & \text{if the link } l \text{ is on route } r, \\ 0 & \text{otherwise} \end{cases}$$ (7)

where,

T_{nk} : passenger demand between origin n and destination k;

T^r_{nk} : number of passengers traveling on route r,

T^r_i : number of passengers traveling on route r operated by airline(i)

T^l_i : passenger demand on link(l) for airline(i);

T_i : total number of passengers carried by airline(i)

Finally, the utility of air route choice behavior is explained in detail, because endogenous variables in market model affect this function directly If one route is operated by airline(i), then the utility of the route r is given as

$$V_{(r|i)r} = \beta_{n1}p^r_i + \beta_{n2}\ln(fr^r_i) + \beta_{n3}t^r_i + \beta_{n4}d_i$$ (8)

- p_i^r fare on route r of airline(i),

fr_i^r : weekly flight frequency on route r of airline(i),

t_i^r : travel time on route r of airline(i) ,

d_i : dummy variables for airline characteristics

$$\begin{cases} 1 & \text{if the airline}(i) \text{ is a flag carrier of region } n \\ 0 & \text{otherwise} \end{cases}$$

$\beta_{n1}, \beta_{n2}, \beta_{n3}, \beta_{n4}$: parameters

3.2 Behavior of Airline

It is assumed that every airline adjusts the level of service, such as fare and frequency, to maximize its profits. Profit is obtained by the difference between revenue and cost, and profit of airline(i) is given as (9). Because the analysis system does not include the whole network of airlines, revenue from passenger is obtained only in the analysis system. Details of the cost function is explained in later section.

$$\pi_i = R_i - C_i = \sum_{r\in\Gamma(i)} p_i^r T_i^r - \frac{Y_i^I}{Y_i^I + Y_i^O} TC_i \qquad (9)$$

π_i : profit of airline(i),

R_i : revenue of airline(i) ,

C_i : cost of airline(i),

$\Gamma(i)$: set of routes operated by airline(i),

Y_i^I : passenger-kilometers of airline(i) within objective network,

Y_i^O : passenger-kilometer of airline(i) outside objective network,

TC_i : total cost of airline(i).

3.3 Assumption of Market Structure

Network structure is examined and the service levels of each airline are shown in Figure 2. The assumptions described below are employed to analyze the aviation market The assumption (1) and (2) are same as Ohashi et al. [17].

(1) Competition of firms is under nash-equilibrium.
(2) The frequency is treated as a continuous value.
(3) The routes operated by each carrier are determined exogenously, airline(A) operates flights on link(1-2) and link(1-3) ; the numbers in parentheses mean origin destination region of the link, airline(B) operates flights on link(2-1) and link(2-3). Airline(C) also operates flights on link(3-1) and link(3-2).
(4) The relation between traffic carried by each airline and the number of available seats supplied by each airline is given in equation (10).

$$T_i^{l(b-e)} = \sum_{r\in\{r|l(b-e)\in L(r)\}} T_i^r \leq s_i^{l(b-e)} fr_i^{l(b-e)} \qquad (10)$$

$T_i^{l(b-e)}$:   traffic on link(b-e) carried by airline(i),

T : traffic on route r carried by airline(i),

$s_i^{l(b-e)}$: number of seats per flight on link(b-e) of airline(i),

$fr_i^{l(b-e)}$: frequency on link(b-e) of airline(i),

( )Network Structure   (Market of airline(A)   ( )Market of airline(B)   ( )Market of airline(C)
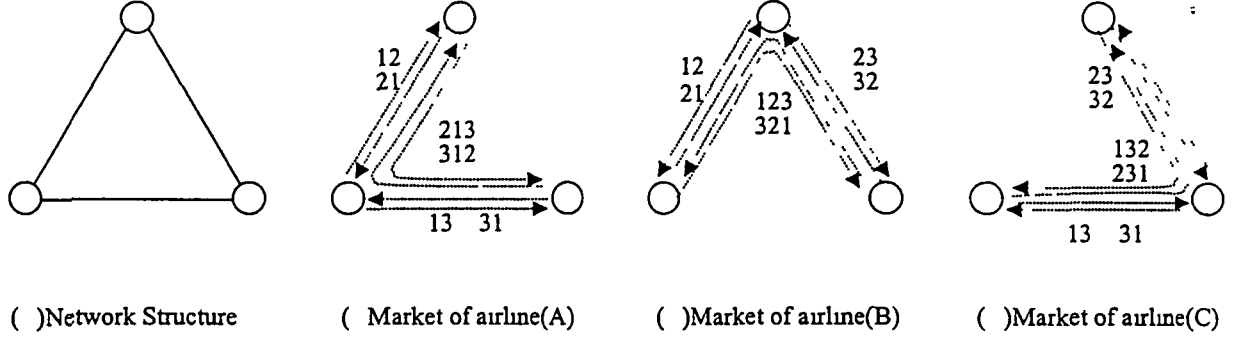
Figure 2. Network Structure of each Airline

3.4 Equilibrium Analysis

The solution of aviation market model is derived using equilibrium analysis. This problem is translated to a constrained maximization problem and the formula is given in equation (11).

$$\max_{p_i^r, fr_i^l \geq 0} \quad \pi_i = \sum_{r \in \Gamma(i)} p_i^r T_i^r - \sum_{l \in \Omega(i)} s_i^l L_i^l fr_i^l AC_i(T_i) - FC_i$$

$$s.t. \quad (\ 10\ ) \tag{11}$$

In order to state the first-order condition for this problem, Lagrangian (Φ_i) it is useful to solve it and the formula is given in equation (12),

$$\Phi_i = \pi_i + \sum_{l \in \Omega(i)} \mu_i^l (s_i^l fr_i^l - T_i^l) \tag{12}$$

μ_i^l is a set of Kuhn-Tucker multipliers. If $p_i^l > 0$, $fr_i^l > 0$ and the Kuhn-Tucker Theorem is employed, the first-order conditions are described below: in Equations (13)(14) and (15),
The related fare on route r:

$$p_i^r \frac{\partial \Phi_i}{\partial p_i^r} = 0 , \qquad \frac{\partial \Phi_i}{\partial p_i^r} \leq 0 , \qquad p_i^r \geq 0 \quad for \quad i \in I, r \in \Gamma(i) \tag{13}$$

The related frequency on link l:

$$fr_i^l \frac{\partial \Phi_i}{\partial fr_i^l} = 0 , \qquad \frac{\partial \Phi_i}{\partial fr_i^l} \leq 0 , \qquad fr_i^l \geq 0 \quad for \quad i \in I, l \in \Omega(i) \tag{14}$$

The related capacity constraints on link l:

$$\mu_i^l \frac{\partial \Phi_i}{\partial \mu_i^l} = 0 , \qquad \frac{\partial \Phi_i}{\partial \mu_i^l} \geq 0 , \qquad \mu_i^l \geq 0 \quad for \quad i \in I, l \in \Omega(i) \tag{15}$$

4. INFLUENCE OF AIRLINE ALLIANCE ON AVIATION MARKET

The incentive to alley with other airlines is increase in profit. The effects of alliance to increase profit are measured using market equilibrium analysis. Alliance effect is divided into the direct alliance effect and the indirect alliance effect. In this paper, cost reduction led by joint expense, and revenue gain led by code share operation and network complement are considered as the direct alliance effects. Meanwhile, the indirect alliance effect, which is obtained through the economy of scale for output, is also considered in this paper
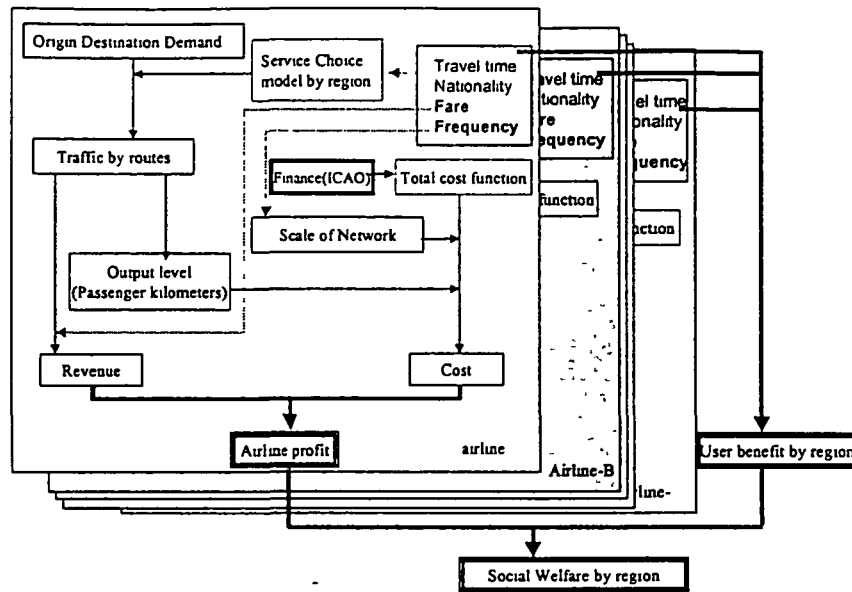
Figure-3 Flow of equilibrium analysis

The influence of airline alliance is measured in terms of change of airline profit, change of user benefit by region and change of social welfare by region. Social welfare is defined as a summation of the change of profit and user benefit at each region. Figure-3 shows the flow of he equilibrium analysis system.

Definition of indices is described below.

(1) **Airline Profit**
This index was already described in setion3.2

(2) **User Benefit**
User benefit by changes in level of service is calculated using the compensating variation. This is determined by the difference of the utility levels before and after service changes. This is given in equation (16) and (17) which indicates the expectations of maximum utility of service choice behavior. Since the total user benefit on one route is obtained by multiplying the number of passengers by user benefit per passenger, the summation of this total benefit of the route is defined as a total user benefit (TUB^n) by region.

$$V_{nk}^{*b} = \ln \sum_{r \in R} \exp V_{(r|k)n}^{b} \tag{16}$$

$$V_{nk}^{*a} = \ln \sum_{r \in R} \exp V_{(r|k)n}^{a} \tag{17}$$

$$UB^{nk} = -\frac{V_{nk}^{*a} - V_{nk}^{*b}}{\beta_{n1}} \tag{18}$$

$$TUB^n = \sum_{nk \in R(n,k)} T_{nk} UB^{nk} \tag{19}$$

V_{nk}^{*b} logsum variables(expected value of maximum utility of route choice behavior for the passenger who travels from origin (n) to destination (k) before service changes,

$V_{(r|k)n}^{b}$: utility specific to combination (r, k) for the passenger who departs from n before service changes;

V_{nk}^{*a} : logsum variables(expected value of maximum utility of route choice behavior for the passenger who travels from origin (n) to destination (k) after service changes;

$V_{(r|k)n}^{a}$: utility specific to the combination (r, k) for the passenger who departs from n after service changes;

UB^{nk} : user benefit per passenger traveling from n to k;

T^{nk} : passenger demand between n and k;

β_{n1} : parameters for travel time;

$R(n,k)$: set of available routes for passengers who traveling from n to k;

(3) Social Welfare

The social welfare at region n (SW^{n}) is determined by summing the change of profit of the airline which sets its hub at region n, and the change of user benefit. It is given in equation (20):

$$W^{n} = \sum_{i}^{I(n)} (\pi_{in}^{a} - \pi_{in}^{b}) + TUB^{n} \qquad (20)$$

π_{in}^{b} : annual profit of airline(i) at region n before service changes;

π_{in}^{a} : annual profit of airline(i) at region n after service changes;

I(n): a set of airlines which locate their base airport at region n;

4.2 Cost Reduction

One of the main effects of alliance is to reduce the cost. In this paper, it is assumed that the cost reduction is caused by the change of cost structure for allied airline. First of all, the cost function of airline is estimated. Limit of linear cost function and Cobb-Douglas cost function has been mentioned in terms of introducing elasticity of input substitution, and Trans-log cost function is usually employed for cost function[18)19)]. However, the focus of this paper is not to estimate cost function precisely but to analyze the influence of airline alliance through the market equilibrium analysis, Cobb-Douglas formation which is shown in eq. (21) is applied to cost function.

$$\ln TC = \alpha_0 + \alpha_Y (\ln Y) + \alpha_N (\ln N) + \sum_{i=1}^{2} \alpha_i (\ln P_i) + \sum_{k} \delta_k d_k \qquad (21)$$

$s.t.$ $\alpha_1 + \alpha_2 = 1$

TC : total cost

Y : output(total passenger kilometer)

N : variable of network characteristics(the number of served cities)

P_1 : unit price of variable cost

P_2 : unit price of fixed cost

d_k . dummy variable for airline attributes

 (k=1 for U.S. carrier, k=2 for Japanese carrier)

$\alpha_0, \alpha_Y, \alpha_N, \alpha_i, \delta_k$: Parameter

Operating cost and maintenance cost composes variable cost, then unit price of variable cost is defined as the variable cost per available seat kilometers. And depreciation, service cost and sales cost compose the fixed, and then, the unit price of fixed cost is defined as the fixed cost per employee. The data for parameter estimation are obtained by ICAO statistics[20)]and OAG[21)]. Figure-4 shows the relation between total cost and output using sample data 3 step least square estimation technique is employed and table-1 shows the estimation results.

What the value of output is 0.776 and less than one indicates the economy of scale related the level of output in this industry It also means that there is an incentive to enlarge output level for decreasing average cost
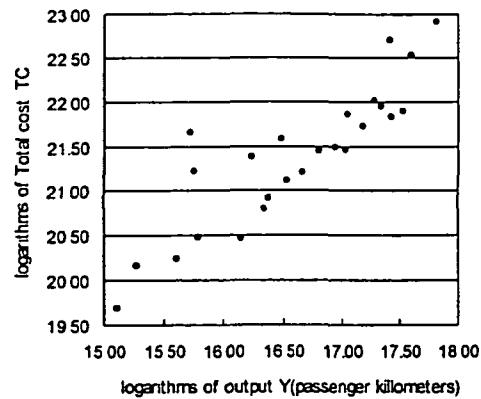
Figure-4 relation between total cost and output level

Table-1 Parameters of total cost function

Variable		Value	t-value
output(passenger kilometer)	α_Y	0.776	14.32
The number of cities served	α_N	0.105	1.31
Available cost	α_1	0.809	20.38
Fixed cost	α_2	0.191	4.81
Constant	α_0	2.770	4.47
Dummy variable for U.S. carrier	d_1	0.085	1.20
Dummy variable for Japanese carrier	d_2	0.141	2.09
Num. of sample		23	
Coefficient of determination		0.996	

With comparing dummy variables for airline attributes, there are positive sign in U.S. airline and Japanese airline. It indicates that both types of airline is high cost structure relative to Asian airlines because dummy variables of Asian airlines is set 0 as standard point. Moreover, it is shown that cost structure of Japanese airline is higher than that of U.S. airlines.

One of the factors that cause cost reduction is joint expanse for fuel, aircraft and promotion Moreover, joint flight operation decreases the operation cost. And joint utilization of terminal facilities decreases service cost. There is an indirect effect of cost reduction which caused by the scale of economy. The average cost is decreased in accordance with increase of output level. If the number of traffic of allied airline increase owing to the higher level of service, allied airline could operate flights with low average cost.

Here, cost reduction effect of allied airlines is examined It is assumed that airline(A) and airline(B) in Figure-2 alley, and unit price of variable cost for the allied airlines decreases at same rate This rate of decreasing variable cost is set α , and the cost reduction effect is examined by the different value of α. And it is assumed that allied airlines pursue to make their own profit maximized, that is, allied airlines cooperate to increase the level of service and they still compete each other when they decide the level of service This assumption remains in the all analysis in this paper

The value for exogenous variables in equilibrium analysis is shown in Table-2 Because the purpose

Table-2 Value of exogenous variables

variable		value	Notes
Demand between Origin and Destination	T^{OD}	250000	Constant at all market
Number of Seat per aircraft	S_i^l	300 seats	Constant for all aircraft
Distance between airport	L_i^l	2000 km	Constant for all link
Travel time	t_i^r	3.39 hour	Direct flight service
		7.71 hour	Transit route
Service choice model for U.S passenger	β_{n1}	-0.345	Fare (n =1~3)
	β_{n2}	0.208	Frequency (n =1~3)
	β_{n3}	-0.240	Travel time (n =1~3)

(1-2) 6.7
(2-1) 6.7

17 7

(2-1-3) 7.9
(3-1-2) 7.9

17.7 (1-3) 6 7
      (3-1) 6 7

(1) airline-A

(1-2) 6.7   (2-3) 6.7
(2-1) 6.7   (3-2) 6.7

(1-2-3) 7.9
(3-2-1) 7.9

17.7   17.7

(2)airline-B

(2-3) 6.7
(3-2) 6.7

17.7

(1-3-2) 7.9
(2-3-1) 7.9

(1-3) 6 7   17.7
(3-1) 6 7
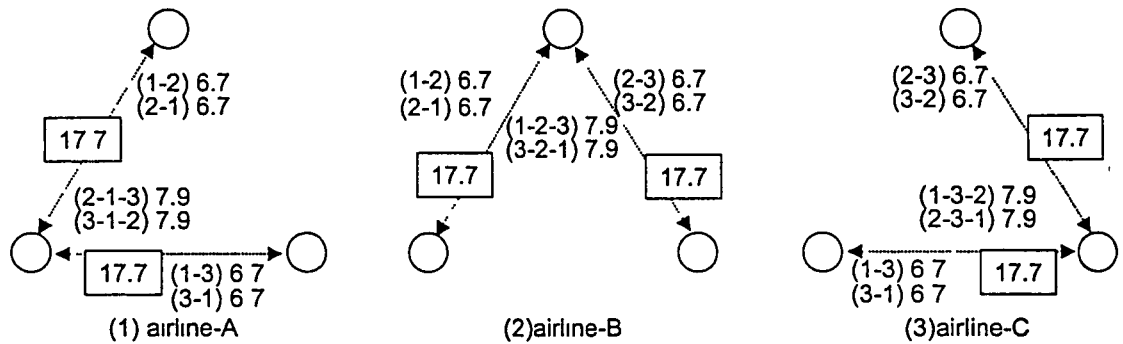
(3)airline-C

note   market, and following number is a fare ¥10 thousand

☐ .frequency per week

Revenue ¥35.2billion, Ccst.¥15.0billion

Figure-5 market equilibrium condition without alliance
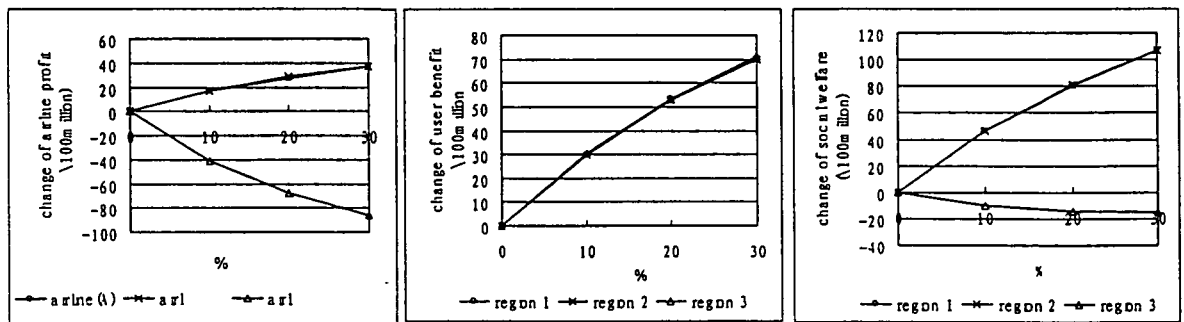
Figure-6 cost reduction effect on airline profit

Figure-7 cost reduction effect on user benefit

Figure-8 cost reduction effect on social welfare

of this section is to examine the cost reduction effect, all airlines assume to be homogeneous in terms of cost structure and their scale and passenger also homogeneous in terms of its preference for airline service. Moreover, the demands on every market assume to be same volume.

Figure-5 shows the market equilibrium states before alliance appears Moreover, figure-6,7, and 8 respectively shows the change of airline profit, user benefit and social welfare with the change of decreasing rate (α) of unit price of variable cost

Figure-6 shows that the profit of allied airline increase with α become small, it means that

achievement to be low coat structure take additional profit. The other hand, airline(C) which could not ally with other airlines decrease profit This is caused by the fact that allied airline can offer lower fare and competitive condition surrounding airline(C) becomes severe. Meanwhile, user benefit at all regions increase with decreasing unit price of variable cost for allied airlines. This is because that influence of cost reduction effect spread to the region where there is no allied airline (Figure-7). Moreover, Figure-8 shows the decrease of social welfare at region 3 because the profit loss of airline(C) excesses increase of user benefit at region 3.

To summarize, decrease of cost structure makes market more competitive and user benefit increase owing to lower fare. However, these results are obtained under the simple market condition such as all airlines have flight to all regions, these results are inapplicable to a case where a market is monopolized by allied airlines.

4.3 Revenue Gain

Revenue increases by obtaining more traffic with higher fare. However, there is an opposite relation between setting higher fare and obtaining greater traffic, high fare does not always produce large revenue. Moreover, between frequency and fare, travel time and fare are also opposite relations. These relations are considered to analyze market equilibrium. In this paper, only increase of frequency and network complement are considered as the effects of increasing revenue.

(1)Frequency Increase Effect

Frequency increase effect is led by code share operation, because code share flights have 2 flight names that include allied partner's flight name. So, allied partner can show passenger the appearance increased number of frequency. For example, if allied airline(A) and airline(B) operate respectively 7 and 5 flights per week on one route before they allied, both airlines could 12 flight per week on the route after they started code share operation fully.

However it is unreasonable that every flight of both allied airlines is operated with code share flight, there is no knowledge for this matter, it is assumed that every flights are operated with code share flight. The fewer number of frequencies between before and after transit is applied to the frequency for transit route.

The sensitivity to flight frequency is examined to analyze the increase frequency effect. Figure-9, 10 and 11 shows respectively the change of airline profit, user benefit and social welfare. Figure-9 indicated that profit of allied airline become with higher rate of code share. User benefit at region 1 and 2 in which allied airline set their base, increase mainly because of increase of frequency Similarly, Social welfare at only region 1 and 2 increase.
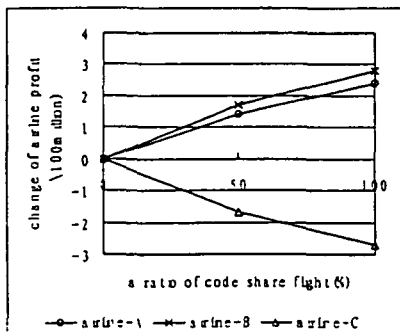
Figure-9 Codeshare effect on airline profit
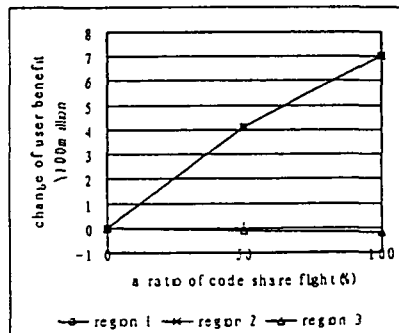
Figure-10 Codeshare effect on user benefit
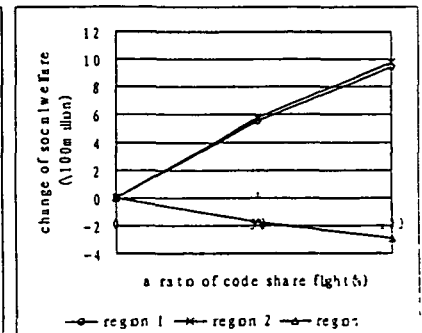
Figure-11 Codeshare effect on social welfare

(2)Network complement effect

Code sharing flight usually makes the network of allied airlines expanded and it can show a convenience of their service with providing the larger number of destinations for passenger. This increase of the number of destination has an effect to enhance the utility of their flight. This effect is defined as network complement effect.

The utility of destination d is set as V_d, the utility on the route is increased by dV, shown in (21), owing to network complement effect.

$$dV = \gamma \sum_d^D \ln V_d$$

(22)

dV : expectation value of maximum utility led by increase of destination.

Y : parameter(coefficient of network complement)

If the utility of all destination added (V_d) is same as $\overline{V}$, (22) is rewritten to (23).

$$dV = \gamma \ln(D + \overline{V})$$

(23)

The greater network in terms of the number of destinations become, the higher utility of the route is. Then, the utility of the route for allied airline is obtained by adding the utility of network complement presented in eq. (23) to eq. (8) .

$$V_{(r|k)n} = \beta_{n1} p_i' + \beta_{n2} \ln(fr_i') + \beta_{n3} t_i' + \beta_{n4} d_i + dV'$$

(24)

It is assumed that the number of added destination can represent the value after sigma in eq. (21). Then, th e different value of Y is set to examine network complement effect on market. Network complement among allied airline(A) and airline(B), is effective on market between region 1 and 2, and between region 2 and 3 for airline(A), and also effective on market between region 1 and 2, and between region 1 and 3 for airline(B).

It is assumed that both allied airlines increase 20 destinations to be served. Figure-12, 13 and 14 shows respectively the change of airline profit, user benefit and social welfare.

Profit of airline(A) and airline(B) increase because they can obtained additional traffic by the network complement effect, and profit of airline(C) decreases. Meanwhile, user benefit at region 3 increases greater that that of region 1 and 2, because the passenger at region 3 receive benefit of network complement in terms of increasing the number of destinations. Figure-13 shows that the increase of user benefit diminishes with the largeness of complement effect. Figure 14 shows that the soocial welfare at all regions increase with increasing network complement effect.
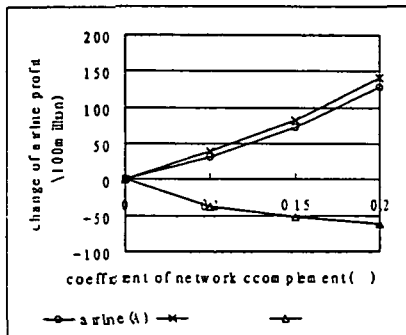
Figure-12 Network complement effect on airline profit
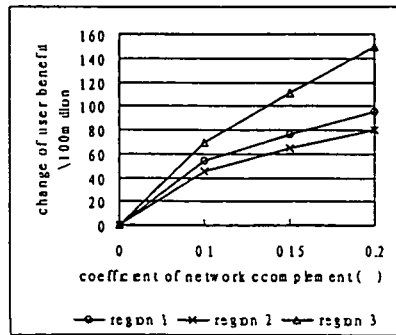
Figure-13 Network complement effect on user benefit
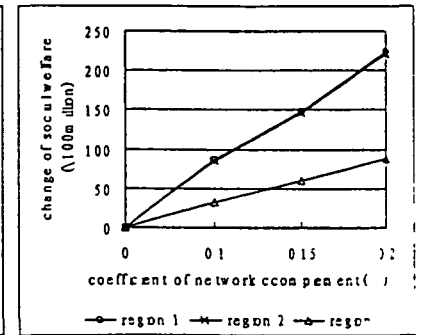
Figure-14 Network complement effect on social welfare

5 - Application

In this section, the applicability of market model, which evaluates the influence of airline alliance, is shown through the equilibrium analysis considering heterogeneity of airline and passenger Heterogeneity of airline is dealt with the different cost structure and scale of production (output level and the number of served cities) and heterogeneity of passenger is also dealt with different preference for airline service.

U.S airline, Japanese airline and Korean airline are respectively applied to airline(A), (B) and (C), and values in table-4 are adopted as components of total cost. Similarly, utility functions of U.S. passenger and Korean passenger estimated in our former research[14] are applied to the utility function of passenger at region 2 and 3. Function of U.S. passenger is also applied to the function of Japanese passenger at region 1. Conditions of the demand volume on each market, aircraft size, network structure of each airline are same as pervious section in this paper.

Three kinds of alliance effect described former section are considered. And then, decrease rate (α) of unit price of variable cost is set 10%. With regard to network complement effect, in case of the alliance between airline(A) and airline(B), it is assumed that both allied airlines increase 10 destinations, and in case of another alliance, it is also assumed that allied airlines increase 20 destinations.

Fig-15 shows the equilibrium condition in the market in which there is no alliance. It shows that airline(A) can not set low level fare comparing with other 2 carries, because of its high cost structure and weak competitive power. Therefore, the traffic of airline(A) is also below that of other airlines largely.
Next, the impact of alliance on market by the change of combination of airlines which make alliance is examined. Figure-16, 17 and 18 respectively shows the change of airline service by the different alliance form. The value in these figures indicates the difference between before and after appearance of alliance. That is, the sign of minus of fare change indicates the decrease of fare, and the sign of minus of frequency indicates the decrease of frequency.

It is found that allied airline increase frequency and non-allied airline decrease frequency. It is also shown that allied airline looks like setting lower fare owing to the cost reduction effect, and it make market more competitive and non-allied airline should set lower fare than before.

Then, the influence of alliance on market is examined. Figure-19 shows the change of airline profit by the form of alliance. Before alliance is formed, the profits of airline(A), (B) and (C) are \6.83 billion, \38.65billion and \25.05 billion. It is expected that allied airline increase profit, however Airline(C) which allies with airline(B) increase profit little. That is, it indicates that the increase of profit by alliance is dependent on the market condition surrounding the allied airline.

Table-4 Variable of the elements for cost function of airline(A),(B) and (C)

	Airline(A)	Airline(B)	Airline(C)
Available Seat Kilometer (10 billion)	592 2	1403.5	381.3
The number of served cities	53	37	49
Unit price of variable cost per employee(SUS)	192392	89976	90797
Unit price of variable cost per available seat(SUS)	64 5	27 5	31 0

Next, change of user benefit is examined. Figure-20 shows the change of user benefit at each region by the form of alliance. The user benefit is increased in all type of alliance That is, the passenger, who lives in the region where there is no base of allied airline, still take a benefit with accordance with increasing level of service of other airlines. User benefit caused by the alliance between airline(A) and airline(C) is not as large as other alliance cases, because complement effect of this alliance form is assumed to be smaller than that of other alliance forms.

note   market, and following number is a fare ¥10 thousand
        ☐ frequency per week
Profit of airline airline-A(¥33 7billion), airline-B(¥40 0billion), airline-C(¥19 6billion)
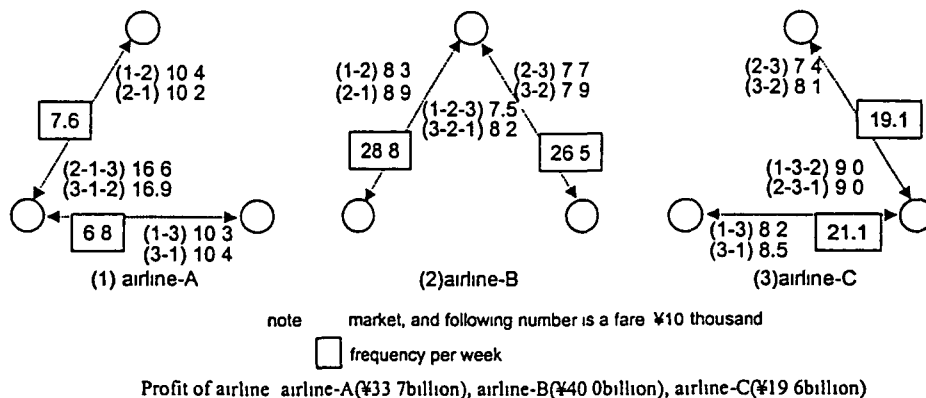
Figure 15   Equilibrium condition before alliance occurs

note   market, and following number is a fare ¥10 thousand
        ☐ frequency per week
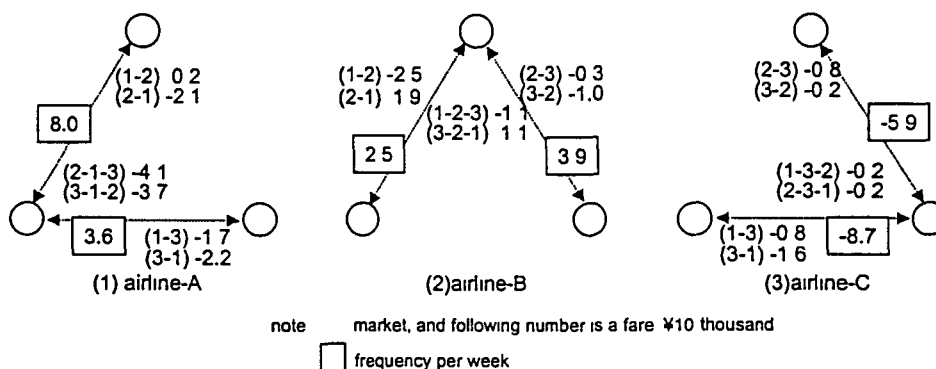
Figure-16   Market condition when airline(A) and airline(B) allied

note   market, and following number is a fare ¥10 thousand
        ☐ frequency per week
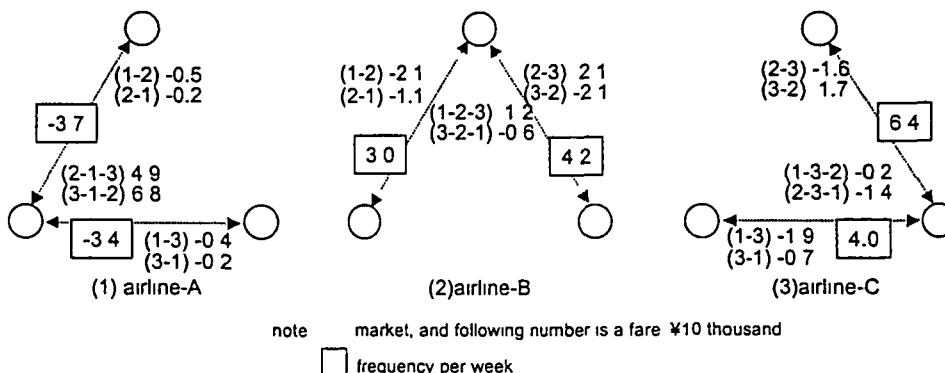
Figure-17   Market condition when airline(B) and airline(C) allied
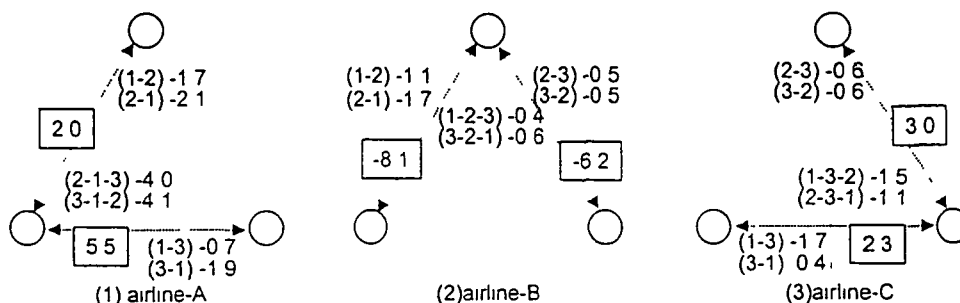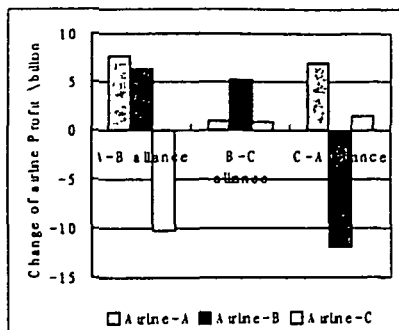
Figure 19   Change of airline profit Figure 20   Change of user benefit   Figure 21   Change of social
          by alliance form   by alliance form   welfare
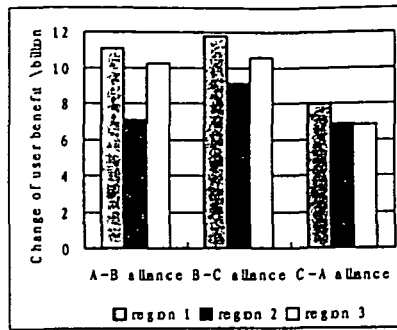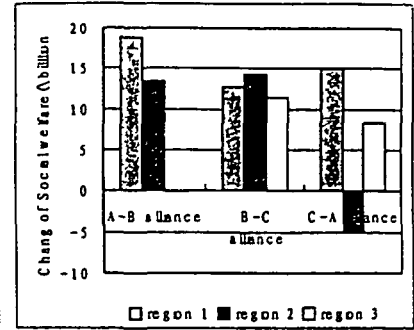
Meanwhile, alliance between airline(B) and airline(C) generates the largest user benefit among all alliance types, because these two airlines, which have a lower cost structure than airline(A), can set much lower fare owing to the cost reduction effect.

The change of social welfare is shown in figure-21. Social welfare at the region in which there is a base of allied airline increase in any alliance cases. However, social welfare at the region in which the base of allied airline does not exist is determined by changes of airline profit and user benefit As we expected, the influence of alliance is largely different by alliance form, and total social welfare of these three forms are respectively, \33.7billion (A-B), \40.0 billion. (B-C), and \19.6 billion (C-A).

Some results described below are obtained through this chapter.
(1) Cost reduction effect of alliance makes market more competitive and introduce lower fare competition. That is, the user benefit is increased by alliance.
(2) Frequency increase effect contributes for to obtain the additive traffic and to gain revenue on the market, and also it makes market condition differ.
(3) Network complement effect contributes to increase profit of allied airline.
(4) If allied airline improve level of service for the passenger who resides in the region where the base of allied airline does not exist, the user benefit and social welfare at this region may increase.

6. CONCLUSION

In this paper, the aviation market model is formularized from the standpoint of microeconomics and influence of airline alliance is examined using equilibrium analysis. However, the results are obtained on the condition that every airline can operate at all regions. Therefore, it is required to analyze properties of international aviation market for the policy making with expanding objective area to be examined and increasing the number of firms.

It is thought that airline alliance will spread to whole international aviation market and that alliance has only positive effect to market, airlines and users. However, after the competition among allied groups, there would be some regions which suffer loss of welfare. Therefore, the research on the forecasting the alliance influence in the long terms is required to make appropriate international aviation market.

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Future developments in the structure
of airline alliance networks

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Introduction

The tendency of airlines to co-operate with each other has been steadily increasing over the past years, and we can currently observe different types of alliances at different stages of development Clearly all of the current groupings are still in a formative stage, and in the coming years, it will be interesting to watch an alliance's internal dynamics and to observe what different *types of alliances* are eventually emerging, and how they are faring This paper describes possible roles airlines can assume within an alliance, discusses two ways of classifying airline alliances, and suggests different types of alliances which are likely to have come forth by the time the initial formative stage is over. A list of factors which are likely to influence the structure and extent of future alliance organisations is also proposed

In order to remain as realistic in its predictions as possible, the paper concentrates on airlines which are currently active on the alliance-front.

Current airline alliances

At the moment, we are witnessing the formation of four separate alliance blocks It must be said that neither of these blocks has reached the fully operational status the members proposed to reach, each of them is in various states of formation, and some of the larger airlines still remain outside any of the blocks

Today, the four spheres of influence can be described as follows

➤ The STAR alliance can be regarded as the most mature of the alliance groupings There are currently six firmly established members (Lufthansa, SAS, United, Air Canada, Varig,Thai) plus a number of affiliates which will join in soon (Air New Zealand and Ansett Australia, Singapore Airlines, All Nippon Airways). STAR is currently the only true multilateral alliance, which means that each member has a full set of co-operation agreements with every other member There are, however, no equity holdings between partners

➤ OneWorld is the recently announced brand of the co-operation between British Airways, American Airlines and their respective affiliates. The initially intended depth of this alliance has been severely curtailed by authorities due to a fear that BA and American would dominate the transatlantic market out of their London Heathrow hub At the moment, there will be Marketing co-operation between BA an AA but no codesharing between these two on North Atlantic routes. Other airlines in the sphere of this alliance (with a dense net of codeshares between them) include Qantas, Cathay Pacific, Finnair, Iberia, Aerolineas Argentinas, LOT and Canadian Airlines as well as the continental European branches of British Airways, such as Deutsche BA and TAT. There are a number of equity ties linking carriers within this alliance

➤ The third large grouping, commonly dubbed "Wings", is evolving around KLM / Alitalia and Northwest Airlines KLM and Alitalia have announced what they call a „virtual merger" A further member to this group might be Continental, pending approval by the US antitrust authorities of Northwest buying a stake in that airline.

➤ The long-established "Qualiflyer" -Alliance, comprising Swissair, Sabena, Austrian, Turkish Airlines and TAP represents the fourth group

➤ There is still a number of large airlines remaining without firm alliance commitment Several have codeshare agreements with „allied" carriers, often reaching into different alliances Prominent as of yet unallied airlines include JAL, Air France, Delta, South African Airways, and Olympic Some seem to hedge their bets, like South African Airways, which has codeshare agreements with both Swissair and Lufthansa, others gravitate towards one grouping but remain cautious about full membership, such as JAL's forging of links with BA

Five reasons to enter an alliance

Co-operation between airlines is not new, but whereas the types of alliances that were forged in the 1980's were mostly technically-oriented (maintenance pools and co-operations such as KSSU, ATLAS), today's alliances are more marketing-oriented There seem to be five main reasons why airlines seek to co-operate with each other·

1. A very strong factor which propagates the tendency towards the formation of marketing alliances between airlines is **customer expectations.** The requirements of the travelling public go towards "seamless" travel to a maximum number of points across the globe, and this goes beyond what a single airline could provide. It seems that in the air transport industry of these days, it is only in remote locations and on very few thin routes that air transport services can be provided in a vacuum.

2. **Defence** Defensive grounds can be active, as a forward defence by consolidating one's position through traffic feed from an allied partner, or passive , for example, by sheltering from competition, entering an alliance dampens or completely eliminates competition with partner airlines[1] and strengthens the carrier's position against outside competitors. The deregulated environment and the fact that competitors might have joined an alliance puts a carrier in a potentially weak position Joining an alliance provides access to resources to strengthen that position[2].

3. **Control of the environment:** This is linked to the Defence motive in the described sense of "competition dampening" On a more active account, a single airline has, to some extent, influence over its immediate task environment, but relatively less leverage over the larger general environment. The alliance, if acting as a representative of its members, is likely to have more negotiating clout vis à vis external suppliers or (possibly in the future) regulators One example for an alliance taking control of its environment, in this case of suppliers, is the proposed formation of a joint Ground Handling franchise system by the OneWorld alliance, which will cover several key outstations The thereby gained independence from external suppliers at important hubs would not have been economically achievable for a single member.

4. **Economies of Density** They occur when unit costs go down as the volume provided increases at a fixed network size Two kinds of Economies of Density have been proposed[3], namely Link Density , which is related to the loadfactors on a flight or City Pair, and Network Density, which measures the efficiency of fleet utilisation over the entire network or a set of routes

5. **Economies of Scope:** These occur when unit costs go down as multiple products are produced In airline terminology, they can also be called "Economies of Network Size"[4] Alliances offer an airline the opportunity to reap economies of network size even though they do not physically expand the number of points they serve themselves Possible sources of these Economies are Codeshares, a broadening of the Marketing presence through joint branding, and access to well-distributed Frequent Flyer Programmes

It must be noted that Economies of Scale do not figure in the above list Scale economies occur when unit costs go down as total production is increased So far, Economies of Scale, which an airline can derive purely from being large in size, have not been observed[5]

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[1] Eisenhard and Schoonhoven (1996) mention vulnerability as one reason to enter an alliance
[2] see Pfeffer and Salancik (1978)
[3] Youssef (1992)
[4] Bissessur (1996)
[5] see Caves, Christensen and Tretheway (1992) Bissessur (1996) added the scope dimension According to his findings, there are no differences in unit costs between carriers of different size as long as the average stage length, traffic density and input prices remain the same Scale Economies do, however, exist at the *production unit* level, for example in case of aircraft Broadly speaking, larger aircraft have lower unit costs (cents per aircraft seat mile) than smaller aircraft

Niche Strategies as an alternative to alliance membership

There is also a non-negligible domino effect in alliancing If all other airlines with whom a carrier competes are allied, thus reap benefits of scope and density and offer their customers a much larger network, the entire competitive environment has shifted so much that the non-allied carrier, who now competes against the might of an alliance, is forced to adapt to it by joining an alliance himself, if he wants to survive The only alternative would be to avoid that changed competitive environment altogether, exit it and seek a new competitive environment, where one would have more might. In other words, retrench and concentrate on dominating a niche market This is an extreme step which would probably require significant structural changes within the airline, but it is theoretically not impossible, especially if the carrier has some prior experience and market presence within that niche. A niche strategy can be based on geography and on function. If the chosen niche is based on **geographical specialisation**, it would not be a completely safe haven from competition, for it would be challenged –and possibly lost- as soon as a sufficiently competent intruder tried to connect the niche region to the outside world This is because the connector can, courtesy of his network membership, bring new customer bases to that niche market Another reason is that passengers have shifted their expectations significantly upwards during the past decade· They demand seamless service, frequent flyer points and global networks, and they seek to fly with those airlines which can meet their new expectations Dominating a geographical niche is thus not a reason for avoiding an alliance, but rather a reason to enter one, for it will translate, in the alliance terminology discussed further down, into being a "Local Champion", who contributes his market dominance to the alliance and reaps in turn the benefits of increased marketing scope The other niche strategy, one which appears to be impervious to at least the *current* alliance movement, is that of **functional differentiation**, for example, that of low-fare, no frills services, and we currently see no low-fare carrier participating in the big alliance game. One straightforward reason for this is the need for a more or less homogeneous fare structure as well as a requirement for similar service levels across alliance partners. There appears to be what we can call a "minimum required structural compatibility level" for an alliance to take place, and sharp differences in service concepts and / or fares seem to be factors which move the strategic group of low-fare / no-frills carriers below this minimum threshold level It would be possible to imagine the formation of alliances between the low-cost carriers themselves, and this is in fact likely to happen at some point But the concept of low fare operations is, in itself, still fairly immature, and different airlines still experiment with various low-fare strategies. For an alliance to take place between airlines, there must be a minimum level of consensus on *how* things should be done Lastly, there is, today, not yet the perceived need for a network between low fare carriers The reason lies again in what passengers have come to expect from the relatively new dimension of cheap, no-frills travel Low-Cost airlines concentrate on point-to-point services, often to secondary airports, many operate very simple reservation systems, and passengers do not, at the moment, expect anything else Thus neither the passenger expectation factor nor the domino effect of having to react to alliances being formed within one's environment, have so far come to influence the low-fare niche universe

We are going to concentrate our discussion of alliances on airlines which remain within the "classical" concepts of fare and structure The alliance phenomenon is fairly recent, and focussing on "classical" carriers yields richer observation material than attempting to discuss the still hypothetical case of low fare airlines

A classification of airline roles within an alliance

There have been numerous suggestions on how airlines can be classified[6]. Since the purpose of this paper is to examine the alliance context, it will be tried here to classify them according to a feature which is highly relevant to their membership in a strategic alliance, namely the *nature and scope of services* provided by a carrier In the following classification, airlines are grouped according to the relative importance they put on serving their home markets versus intercontinental flights to feed that home market[7], or transcontinental flights which do not concern the home market at all. The notion of "home market" is feasible because all of the current actors in the alliance game are airlines which have traditionally served a medium- to shorthaul market around their hub(s), an area where they enjoy a strong market presence and possibly even dominance; none of them is a pure longhaul carrier, such as Virgin Atlantic. But airlines do differ in how much weight services within their home market have relative to all of their flight operations and revenues.

Concentrating on those airlines which are currently members or potential affiliates of one of the four alliance blocks allows one to categorise the following different strategic groups

> ➢ **Local Champions.** Short- to medium haul airlines, based around one or two main hubs and possibly several secondary hubs within their respective home region They do operate limited long-haul services, some of these intercontinental operations- for example, Finnair's routes to Asia- are high-yield and generate significant revenue, but these often constitute a relatively small part of overall operations
> Three European carriers- Sabena, Air Portugal and Iberia- stand out in this group as concentrating their long-haul services with extensive operations to specific regions with which their home countries have former colonial and continuing cultural ties, but few or no flights to other intercontinental destinations. Some local champions face significant competition in their home markets (especially in North America and Western Europe), others are true niche carriers in that they serve markets where they enjoy a high presence and relatively little competition. Some of these markets can be quite attractive due to their wealth (for example, Northern Europe) Other niches are the so-called long-thin routes, for example some routes to Africa or South America.
> In brief, the Local Champion type of carrier concentrates on serving its *own* world
> ➢ **Long-Haul Operators** Intercontinental flights constitute a fairly high proportion of their total flight operations and revenues Some of these airlines are in this category due to the geopolitically "remote" location of their home, such as Australia/ New Zealand or South America As Flag carriers, their mission was to link their country to the "Rest of the World". They typically connect their home market, where they enjoy a dominant or close to dominant position, with the respective important business centres on other continents
> ➢ **Transcontinental Connectors** These airlines truly aim to serve the *whole* world, they operate to several continents and have the capability to link two continents through their home hub on a third[8]. They often also operate dense local networks, but these do not necessarily constitute their primary "raison d'être". The role of Transcontinental Connector requires a centrally located homebase, such as in Europe, North America or a central location in Asia

In many cases, the above described division runs also close along the lines of multiple roles Whereas Local Champions concentrate on operations within their home market, a Transcontinental Connector often tries to fulfil the two other roles, too

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[6] see, for example, Gialloreto (1986), Kling and Smith (1995), Ter Kuile (1997), Staniland (1997), Berardino and Frankel (1998)

[7] there can be of course, also short- or medium haul flights which feed a home market The intercontinental attribute was deemed more expressive because the alliance phenomenon is here looked at in a *global* context

[8] For example American Airlines links Europe with South American points through their hub in Miami, North American and African destinations are linked through hubs in Europe and several Asian carriers link Europe to Australia

The current situation in the alliance scene, taking into account carriers with firm commitments or which clearly gravitate towards one alliance, can be depicted as follows·

(Fig 1)	STAR	One World	WINGS	Quali-flyer
Transcont.-Connectors	United LH SIA Thai	BA AA Cathay	KLM / AZ NWA	Swissair
Longhaul Operators	AC ANA VARIG Air NZ	A Arg Qantas		
Local Champions	SAS	Iberia Finnair LOT		Austrian TAP THY Sabena

Classifying alliances according to the degree of diversity

The above list is a snapshot of a situation which is constantly evolving . What comes to the eye is the difference in homogeneity[9] between the alliance groupings: STAR members remain in the cluster of globally, and even from three continents transcontinentally operating airlines (with the exception of SAS, which, instead, contributes access to the high-yield, but somewhat peripherally located, Northern European market). In other words, the division of work within STAR is more along geographic, less along functional lines. The other truly "World-spanning" alliance, OneWorld, includes airlines which are much less homogeneous; there is a clear functional role allotment between the Local Champions and the Transcontinentals Local Champions contribute access to markets, while the Transcontinentals connect them.

The Qualiflyer alliance in its current state concentrates on Swissair acting as a Transcontinental Connector and at the same time as a Long-haul operator, linking some of the most important hubs on several continents to a dense European joint network, in addition, there are some long-and-thin intercontinental markets from the heritage of other member airlines. It remains to be seen whether an alliance which is built around one single "senior member" will be successful in the long run[10].

The measure of Diversity looks at the different types of airlines involved in a block It is possible today to distinguish between relatively homogeneous alliances, where all members are from within the same strategic group (such as STAR), and where the division of work is defined along geographical lines, or alliances that are more heterogeneously composed (such as OneWorld), where airlines differ in terms of their function Homogeneous alliances get their "local feed" from the home markets of the Transcontinental Connectors, whereas within a heterogeneous alliance, there are single- and multiple-role carriers alike. The reason why this distinction is relevant is that the governance, the power structure and the nature of contributions and benefits sought by members differ between the two types[11] Single-role airlines depend on one defined market, they need to provide this market with a connection to the world in order to meet increasingly sophisticated customer

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[9] this had been predicted by Oum, Taylor and Zhang (1993)

[10] ibid

demands The alliance will increase their scope Those airlines which have multiple roles are more exposed to competition on various fronts, they also face the danger of becoming too complex as organisations if they try to be leaders in each of their roles This is a weakness of the homogeneous alliance and possibly the main reason why this type is unlikely to persist beyond the formative stage of the alliance. At some stage, multiple-role carriers will recognise the benefits of a division of labour, and allied Local Champions can provide a "local shield" for airlines with transcontinental capability, and they also provide feed for their connector role, in other words, economies of density

We can thus expect Diversity to be a temporarily relevant dimension, since it depicts a difference that is salient during these "early days" of alliance building, but is likely to disappear during the coming years

The reason for this probable loss of relevance is that each intercontinental carrier already has a subsidiary or affiliated airline serving as a local feeder. Within STAR, the plan of devising a scheme for "second-tier-membership" to accommodate these local contributors into their "seamless service" concept has already been discussed. Starting out as a homogeneous grouping is organisationally easier and yields a world-spanning network (and the associated marketing effect) relatively quicker. In a consolidation phase, however, the global hubs will need local feed which at many points must go beyond what the member airlines themselves can provide. Possibly, the second-tier members will not be fully integrated into the alliance, it is likely that hierarchical differences will arise in order to ensure a less complex alliance management structure. This leads to a second possible classification, which could explain a considerable part of the future structure of alliances:

Classifying alliances according to the degree of integration

This second dimension, which is likely to persist, measures the tightness of coupling between members. The higher the degree of interaction, the more the alliance membership is likely to influence the member airline's internal structure. Links between airlines are of different quality, ranging from mere route-by-route co-operation over marketing agreements and joint Frequent Flyer programme recognition up to equity investments and seats on each other's boards to a joint governance body (as it has been already developed by STAR) Leaving majority equity investment and managerial control of a larger airline over a smaller airline aside – it has been suggested that a true "alliance" is between independent partners where each partner has the possibility to opt for the dissolution of the agreement[12]-it is possible to make out two broad degrees of interaction[13] between two or more alliance partners :

1.) <u>Low density / Alliances based on exchange</u> Contributions and outcome are intended to be proportional The actor's orientation is primarily towards their own goals, co-operation is limited to certain routes

2) <u>High density / Alliances based on integration</u> These alliances display a more collective orientation The focal unit is the overall alliance route network and the way services on it are sold, not an individual city-pair Integration demands a deeper level of commitment from each actor, and therefore often requires an adaptation process[14] Integration-based alliances feature increased interdependence between members. High interdependence does not necessarily have to involve equity, it is already present when partners incur costs and / or change their operational focus for the sake of the alliance, for example, by pulling out of some routes or investing heavier in certain markets The degree of integration influences the quality and nature of an

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[11] Smith et al (1997)

[12] Brewer and Hooper (1998)

[13] ibid

[14] Easton (1992)

interaction This in turn defines the thickness of the boundary between the airline and the alliance organisation This becomes very relevant when an airline must decide on its alliance policy, and it is the boundary issue which has a large impact on the internal structure of the airline itself, not just on its marketing scope. It is along the dimension of interaction that the alliance will, eventually, start to act as an organisation in its own right, both to the outside environment and towards its constituting members Increased integration implies, as stated before, a reduction in boundary strength between actors[15] and, thus, increased interdependence between them At high integration levels and permissive boundaries, the member airlines will move towards constituting organisational units of the alliance, rather than being independent contributors to it It is also at the level of integration that we are likely to witness a slowing down in the rapidity with which alliances are tied and dissolved. Mutual interdependence between airlines will create the need for a stable structure of the organisation within which this interdependence is housed, i.e., the alliance.

Another interesting aspect in the future morphology of alliances, which is related to integration, is that of exclusiveness of a network[16], or the degree to which an alliance is insulated from other alliances. This is the outside boundary of the alliance. An example for this is the recent cancellation of a codesharing agreement between Varig and Japan Air Lines. A codeshare on the "long-thin" routes between Brasil and Japan might have made business sense, but it could not be upheld due to Varig's membership in the STAR alliance, which comprises an exclusivity clause

A possible alliance scenario for the near future

It is unlikely that any airline alliance group will, at least in the medium term, be able to behave like a true organisation in its own right The reasons for this lie in the regulatory environment as well as in the fact that very few airlines actually wish to give up a large amount of independence

What we can nevertheless observe is that there is a wide variance in airlines' willingness or ability to enter different levels of integration, and that these differences in tightness of links are likely to define the structure of airline alliance groups as they approach maturity.

It is suggested here that alliance types can be classified along the lines of integration levels between members. It is possible to distinguish at least three genuine types of alliances At the heart of the first type of alliance ("Alliance X" in Fig 2, see below), a small number of partners ("Full Members") co-operates tightly, possibly even relinquishing some authority to a joint steering board The agreements between these full members are likely to be fully multilateral and exclusive, as is already the case with the STAR alliance Full membership yields the benefit of maximum environmental control, for in addition to having a full say in matters concerning intra- alliance governance, it is at the alliance's core where the nature of interactions between the alliance group and its environment will be defined

The "Full Members" are supported by the "Second Tier Members" These are typically affiliated feeders which collaborate more tightly with one of the Full Members (possibly also due to equity ties) than with the others The distinction between Full Members and Second Tiers is hierarchical, Second Tier Members do not have the same power within the alliance, but they receive density and scope benefits and they also benefit from operating in a more "sheltered" environment

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[15] for a discussion of boundaries in hybrid organisations, see, for example, Borys and Jemison (1989)
[16] Easton (1992)

Lastly, there is the "**Sphere of Contributors**", which consists of airlines which co-operate with the alliance on a route-by route basis. "Contributors" can co-operate with airlines from different alliances, they seek co-operation based purely on exchange.

Some of these Contributors might be Long-Haul operators from relatively remote locations which seek optimal connections between their home hub and a small number of points on other continents, or they might be small regional operators which are contracted by one of the allied carriers to serve a specific route for them

(Fig 2) Types of alliances
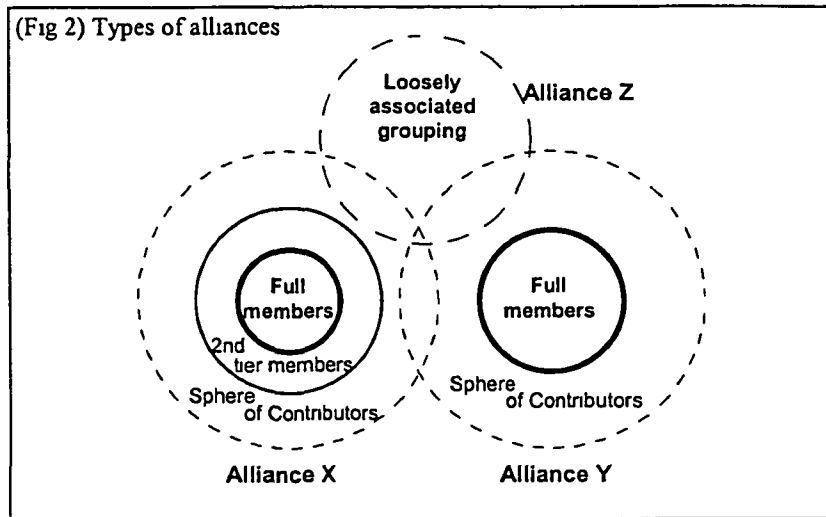
The second type of alliance (Alliance Y") is structured similarly, but there are no second-tier members Membership is "all-or-nothing", and this type is likely to either have a smaller or less densely integrated core, or it might rely on a greater number of external contributors to its dense core The "Alliance Y"-type is one reason why it will be difficult to continue applying the much-used differentiation of "Junior Members" versus "Senior Members" to every alliance, when "Junior" refers to smaller airlines which are most likely to be Local Champions "Junior" should, in fact, rather refer to less tightly integrated partners. If the alliance aims at providing a network literally around the globe, there might be a tendency to maintain leadership of an alliance between the Transcontinental Operators, which give it its global frame In certain markets, however, the Local Champion will have traffic dominance over an airline which might be much larger in overall size Hence, they will have negotiating clout in matters concerning that specific market Their power will thus not directly depend on their size, but rather on the attractiveness of the market they contribute to the alliance

There might be a third type ("Alliance Z"), a more informal grouping of otherwise non-allied carriers with some codeshares between each other and reciprocal Frequent Flyer Programme recognition on some routes The level of exclusivity is very low This third type is likely to develop if in the future regulatory limitations on co-operation (be it codeshares or majority stakes in foreign carriers) are going to be so strict that the building of a functioning, efficient alliance will be made impossible Type Z permits maximum autonomy to carriers, while it will still be possible to establish "seamless" travel on certain routes between two airlines Benefits of "Defence" and "Scope" are, however, likely to be much smaller than in the other two types of alliances.

Drivers of alliance structure

All three alliance types are structurally distinguished by the different levels of interconnectedness, or tightness of coupling, between their members It seems that there are four prominent factors determining the differences in tightness of coupling, namely Regulation, Passenger Expectations, the Uncertain Competitive Environment, and Internal (managerial) Resistance. This can be depicted as follows:

(Fig 3) Forces which determine alliance members' integration levels
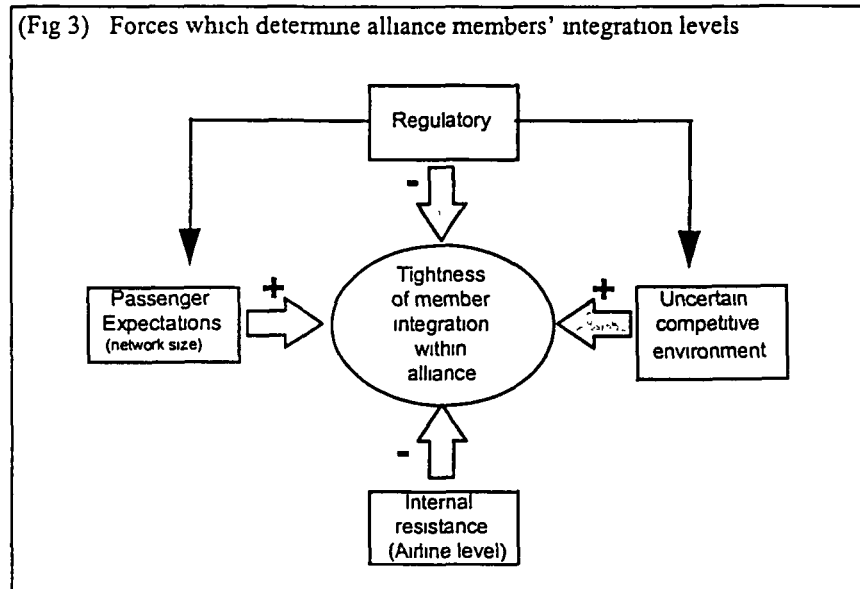
Two factors positively influence the tightness of co-operation between alliance members

First, and as discussed above, Passengers have come to demand a type of service which is impossible to provide for a single airline The need to fulfil these enhanced expectations induces tighter co-operation between carriers Second, the increased level of possible competition between airlines and the continuing deregulation of markets has led to greater uncertainty in the airlines' operating environment. They are turning to co-operation as they seek to control this uncertainty

The next two factors work *against* tight co-operation between partner carriers· There is, within airline management, still a large reluctance to give up independence and to relegate decisionmaking to some entity outside the own company There is also the hurdle of cultural friction: As firms co-operate, distinct company cultures –and, in case of airlines, invariably nationalities- meet, and even though procedures at the "Production-level" of airlines (i.e maintaining and flying the aircraft, dispatching the passengers) are highly standardised world-wide, culture still is likely to have an important influence on how and why things are decided Even though they might consciously favour an alliance membership, managers are likely to put their own airline's interests above those of the alliance, thereby working against integration.

Lastly, is interesting to note the impact of the regulatory environment· On one hand, there is a strong resistance against approving alliances which would dominate a certain market or a certain hub airport This has a negative effect on the tightness of member coupling, as it can prevent codeshares and joint pricing But regulation has also its impact on customer expectations as well as on the airlines' requirements for environmental control As discussed, the opening of markets has changed what customers expect from air travel Moreover, the mere fact that strong regulatory forces govern air transport is inducing airlines to co-operate with each other in order to maximise their influence on regulators A further factor increasing the need for environmental control is that

uncertainty levels and competitive pressure on airlines increase due to the gradual reduction of traffic regulation, as 5th, 6th and 7th freedom rights become more common, there are more possible competitors which can access markets.

Conclusions

Given that in the future, almost every airline will be affected by the alliance phenomenon and that one of the determining factors of an alliance's structure is going to be the levels of integration of its members, the question for airlines during the coming years will be not so much whether or not to join an alliance network, but rather, to what extent they can and should integrate themselves in such a network

The structure of these networks will depend on a number of factors (Regulation, Passenger Expectations, the Need for Environmental Control and Internal Resistance), and it can be expected that the regulatory framework is going to play a prominent role in determining the possible levels of integration.

Since alliance networks are likely to be heterogeneous in their membership, that is, constituting members will be airlines of different sizes and operational profiles, there will be some development of an internal hierarchy within the alliance. It is argued that a member airline's hierarchical position within the alliance will depend on its degree of integration and on its scope. The influence of the *extent* of the scope (which is likely to be a result of overall network size) will be somewhat mitigated by the *nature* of that scope In other words, an airline needs not necessarily operate a large network in order to exercise influence within an alliance, as long as it contributes an attractive market to it.

The managerial implications at the level of the individual airline are twofold.

1. In order to secure an optimal position within an alliance network, an airline should seek to clearly place itself either in a "Connector" or in a "Local Champion" role The key is clear dominance of a certain market

2   At the same time, since it is not yet very clear what degree of interaction and integration the regulation autorities will allow, airline management should be wary of giving up too much independence too fast. They should be prepared to be making concessions (for example, giving up certain routes to be served by a partner) at some point, but these concessions will only make sense if they are to be operating in tight co-operation with partners, and within a long-term time framework

In these "early days" of alliance formation, airlines must strengthen their core, but should at the same time maintain non-core markets in order to remain independent –for the time being There might be no imperative need for participating the current "alliance frenzy", where many an airline rushes into agreements for fear of being left out of alliances The final form of airline alliances has not yet been defined, and a cautious approach to alliancing might be recommendable

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DISTINCT FEATURES OF LASTING AND NON-LASTING AIRLINE ALLIANCES[*]

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Abstract

Majority of studies in airline alliances are primarily impact-oriented In this paper, we will take a proactive approach to the airline alliances by directly identifying the underling differences and characteristics between lasting and discontinued airline alliances. The primary objective of this study is to derive some acute patterns about the components that are being employed in the alliances' strategies Based upon a comprehensive relational database of alliances involving top 50 carriers in the world with each alliance characterized by 14 key ingredients, two research databases are subsequently created The database of lasting alliances consists of all alliances that were formed prior to January 1, 1998, but still in effect by the end of 1998, with a total of 297 alliances The database of non-lasting alliances consists of all alliances that were terminated between 1995 to 1998, with a total of 161 alliances

We apply the factor analysis to uncover any meaningful patterns that may emerge from lasting alliances and non-lasting alliances. We observed that alliances jointly targeting at customer loyalty and operations integration, in particular, containing joint marketing, flight scheduling, joint FFP, sharing airport facilities, and ground support, will likely be the norm of lasting alliances Bilateral code-sharing with serious financial trust and commitment (through pool agreement in revenue/costs) is another distinct feature of lasting alliances As for non-lasting alliances, we found that the leading cause for termination is due to engagement in non-core and non-customer-oriented activities in joint purchasing, ground support and IT co-operation Alliances engaging solely in code-sharing, joint operations, or joint marketing without other substantial commitment are likely to fail or temporal and short-term All these findings are further validated by a logit model

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1. Introduction

When KLM first formed an alliance with Northwest in 1989, there were many skepticisms Indeed, airline alliance was at that time still a relatively novel form of business strategy, thought to be transitory inter-organizational devices and adopted by weaker airlines to cover projects they felt inadequately resourced to tackle alone However, as the last decade of this century wanes into the next millennium, airlines are gradually realizing the importance of the alliance strategy. Now, every major airline is engaged in alliance making

One of the earliest alliances was formed in 1948 between Aviaco and Iberia Then, Aviaco simply took equity stakes in Iberia and operated many routes on behalf of Iberia Since then airline alliances have been scarce and few, with a handful taking place each year until the early 1990s

Air France was an early advocator of alliances It partnered both major international and domestic airlines from the 1940s to the 70s, a time when most airlines were oblivious to the alliance paradigm Some airlines that Air France worked with include Royal Air Maroc (1947), Tunis Air (1948), Middle East AL (1949), Air Afrique (1963), Air Mauritius (1967), Cameroon Airlines (1971), and Air Gabon (1977) All were bilateral agreements The early alliances took the form of joint flights, maintenance consortiums, schedule co-ordination, ground handling, through fares, management contracts and catering joint ventures. Over the time, with the development of Computer Reservation Systems (CRSs), early alliances in joint flights has been evolved into code sharing, a popular form of alliance agreement in the 1990s.

The first modern day alliance started in 1975 when Middle East Airlines code-shared with Iberia on the Madrid-Beirut route And the first Frequent Flyer Program (FFP) partnership started on January 1980 between Air UK and KLM Royal Dutch Airlines. The innovation of joint FFP and many others have added new dimensions to diverse forms of alliance agreements

On the whole, airline alliances in the 1980s were less primitive and better organized There are a few likely reasons for the change Firstly, there has been a technological advancement and the airline industry was quick to integrate this new knowledge into both its routine and strategic agendas Secondly, partnerships are evolving from a short-term perspective to a deeper, more strategic relationship Co-operations between airlines are shifting from secondary to primary operations integral to the airline業business Thirdly, due to the increasing emphasis on the co-operation of primary operations, more intellectual capital

has been invested in the alliance negotiations and implementations A task that used to involve only middle management now requires the expertise and deep involvement of the top executives

Going into the 90s, the alliance predicament made a penultimate turn and went into overdrive Airline alliances are the order of the day The general consensus is that if an airline doesn't join an alliance, it will be left out Big players like British Airways, United Airlines, American Airlines, Lufthansa and Singapore Airlines consider the alliance strategy a top priority in their business plans For example, British Airways' aggressive alliance strategy takes many forms, including general sales agencies, joint freight flights, franchise, joint FFP, joint airport lounges, reciprocal ground handling, joint purchasing and code-sharing

Several agreement ingredients from early decades stood the test of time and are still popular forms of alliances today They include code-sharing, joint FFP and ground handling In addition, many new features are created that will shape the alliance of today. Examples include joint advertising and promotions, airport slot sharing, financial/capital access arrangements, joint purchase and repair of spare parts for Boeing 777 aircraft, shared use of hangars, engine test cells, joint development of technical and training manuals Another key trend for the 90s airline alliances is that it is no longer limited to bilateral alliances anymore.

One of the earliest consortium alliances is the Global Excellence Alliance formed in 1989, including Singapore Airlines, Delta Airlines and Swissair The alliance had a code-share and block seat arrangement on SIA's Singapore-New York/JFK service via Europe Also, there was a joint purchasing company based in Zurich with branches in Atlanta and Singapore Singapore has since left the Global Excellence Alliance in 1998

While the Global Excellence Alliance was considered by many to be an equitable accomplishment, not all consortium alliances succeed In 1994, the Alcazar Alliance failed to take off because the four European carriers (KLM, SAS, Swissair and Austrian Airlines) could not agree on the US partner While KLM resolutely stuck by its alliance with Northwest Airlines, the other three potential Alcazar partners preferred Delta Air Lines as the US partner

The most widely publicized alliances in recent years are Star Alliance and Oneworld Star Alliance started with United Airlines, Lufthansa, Thai Airways, Air Canada and SAS Besides having joint airport lounge access and joint FFP, the group is also merging their sales efforts with, for instance, a joint Star sales office in London The rivaling Star Alliance is Oneworld formed by American Airlines, British Airways, Canadian Airlines, Cathay Pacific and Qantas in September 1998 Upon formation, more than a dozen working parties were set

up, covering issues such as airport transfers and infrastructure, marketing, information technology, FFP, and employee training and communication, while the code share component is still subject to regulatory approvals

Currently, there are over 500 alliance deals among individual airlines However, it is the increased diversity in the nature of the deals rather than the accelerating number that is significant Alliances are no longer mere loose arrangements between a few airlines to share flight codes and cross-sell tickets Rather, they are aiming at virtual mergers, despite national rules forbidding foreign ownership

There are many facets of the airline alliances that are worth studying An especially intriguing feature of airline alliances is the many possible partnership combinations It will be interesting to anticipate the impact of impending or fresh alliances Similarly, what will happen to an existing alliance if a partner leaves or if a new partner joins? How does a change in the member structure affect the alliance as a whole and individually? For example, while Singapore Airlines is a part of the Global Excellence Alliance, it also seeks to join Star Alliance After signing a pact with Lufthansa, Singapore Airlines went on to close bilateral tie-ups with another Star member SAS in 1996 By having more business linkups with individual Star members, Singapore Airlines may find it easier to gain access to the alliance it is eager to form an association with Furthermore, Ansett Australia and Air New Zealand, both regional alliance partners of Singapore Airlines, are reportedly being sought after by Star Alliance With the increased dynamism of airline alliances, the possible explanations for airlines wanting to jump on the alliance bandwagon will grow

It is thus necessary to conduct a comprehensive research study to record and account for the growing trend, and the reasons behind it One cannot ignore the alliance fracas for it has grown beyond expectations Because of the nature of its extensive scope (from the reasons for formation or failures, the question of effectiveness, and the advantages and disadvantages among other issues), a multidirectional study on airline alliances is inevitable Furthermore, because alliances have undoubtedly become an important element in the airline industry, it is essential to ensure that future development of airline alliances head toward a positive and constructive direction

Oum et al (1993) identifies two models for global airline alliances The first involves the expensive strategy of a mega-carrier creating an alliance by taking equity shares in several junior partners operating in other countries and continents The lead carrier is inevitably exposed to financial risks deriving from the market performance of these subordinates The

only real example is the global alliance orchestrated by British Airways, although the KLM-Northwest grouping has certain similarities The second model is defined by an alliance between partners in several continents, each of which is supplemented by regional feeder airlines This is much less expensive and risky, and thus more popular, strategy, often involving extensive code-sharing A recent example is the 1994 global code-share alliance between United and Lufthansa

Recently, Hanlon (1996) discusses how the patterns of alliances have developed in the airline industry. He proposes that alliances be horizontal, vertical or external in nature and analyses why one form prevails over the other According to him, horizontal alliances are those between firms selling in the same product or service market, vertical alliances are those with suppliers, distributors or buyers; external alliances are drawn up with potential entrants or with the producers of substances or complements in other industries

It is well known that there has been an explosion in the number of alliance formations since 1993. These alliances take up a variety of forms in terms of the number of partners involved, the kinds of strategies employed and so on Some of these alliances last till today while some were discontinued shortly after their formation No study, to our knowledge, has ever been done to help explain these occurrences This motivates the present research, which hopes to provide some explanations as to why some alliances continue to prosper while some were discontinued In particular, by studying the airline alliances that are taking place in the airline industry in the past decade, we aim to identify underlying characteristics that pertain to alliances that last or discontinue.

The rest of the paper is organized as follows Section 2 explains how the research data set is created In Section 3, we get into more detail analysis in factors that are playing key roles in the lasting and discontinued alliances Factor analysis models will be used for this purpose Section 4 attempts to develop a simple predicative model on whether an alliance appears to be lasting or non-lasting A logit model will be used to predict/classify the failure of an alliance and to validate key findings in factor analysis The final section is the conclusion

2. Research Data

2.1 Sample Airlines

The main information source for this paper was the yearly alliance surveys published by *Airline Business* for the period of 1994 to 1998 Each survey can be found in the June or July

issue These surveys were relatively comprehensive as most of the operating airlines were covered These five surveys formed the core data of our research

As the number of airlines covered in the survey was too many to be entered into the database given our time constraint, fifty top airlines, together with their partners, were selected as the basis of the research These 50 top airlines were chosen based on the *Business Traveller* Best Airline Survey conducted in 1996 (see Appendix A) The reason for using a 1996 survey, instead of a more recent one, was because 1996 fell in the middle window of our study period The top fifty airlines and their alliance partners would form a representative sample for the population These 50 airlines are treated as **initiating airlines**, in the sense that any alliance involving one of these 50 airlines will be captured in our database On the other hand, the number of **participating airlines** (that is, as a partner to one of 50 initiating airlines) is much bigger than 50 since there is no restriction on it

2.2   Primary Databases

The data made available by the *Airline Business Annual Alliance Survey* were the alliance 僵 members, the date when the alliance commenced, and the details of the alliance, for examples, code-sharing, joint marketing co-operation and etc

Not all ingredients covered in the surveys were used in the research We started with twenty-five attributes Due to data sparseness of some attributes, we have consolidated into 14 key ingredients, as summarized in Table 1 More specific details on the content of each ingredient can be found in Appendix B

For the ingredients that made up an alliance, binary coding is used one (1) being the presence of the ingredient while zero (0) representing the absence of the ingredient The number of alliances captured in this study from 1994 to 1998 and the corresponding frequencies for each of 14 ingredients are summarized in Table 2

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Table1: Alliance Ingredient Code

Code	Ingredient
C01	Equity
C02	Joint FFP
C03	Code-sharing
C04	Block seat and space arrangements
C05	Joint marketing
C06	Joint purchasing
C07	Ground support
C08	Airport facilities sharing arrangements
C09	Flight scheduling
C10	Pool agreements (revenues and costs)
C11	Franchise/ royalty
C12	IT co-operation
C13	Joint operations
C14	Commercial agreement

Table 2: Number of Alliances in the Primary Databases & Frequencies of Ingredients

Year	Total	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14
1994	196	38	49	86	23	39	8	26	7	14	5	3	5	47	1
1995	238	40	42	110	27	40	8	35	12	17	20	5	5	58	3
1996	286	44	60	141	46	40	11	46	18	23	15	2	5	58	5
1997	314	32	69	170	51	37	10	47	20	30	25	2	8	53	4
1998	345	33	98	230	59	56	4	67	38	37	22	2	15	43	7

Source The yearly database is directly extracted from *Airline Business Alliance Survey* (1994 – 1998)

From Table 2, it is evident that the most popular ingredient sought is the code-share, followed by joint FFP Five primary databases captured 1379 alliances Of course, majority of them are recurrent ones

After having obtained the original data required, we need to find a way to organise and manage the huge body of data Since the purpose of this study is to investigate the differences between lasting alliances and terminated ones, the data must be flexibly arranged to allow queries to be made For this, we decided to develop a relational database by using MS Access, which allows us to create meaningful secondary databases This happens to be a quite tricky exercise In particular, we must avoid double counting of the alliances

2.3 Construction of Research Databases

After developing and integrating the five primary databases (on the yearly basis) into a relational database, we them created our research databases by conducting specific queries First, we generated five sub-databases, namely, alliances discounted in years 1995, 1996, 1997 and 1998 Preliminary information on these five sub-databases is presented in Table 3

Table 3: Terminated Alliances in Different Years & Frequencies of Ingredients

Year	Total	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14
1995	17	2	11	4	0	1	0	0	0	2	0	1	0	3	0
1996	34	2	6	15	3	6	0	1	1	4	1	2	0	11	1
1997	43	9	5	17	11	6	1	4	1	3	0	1	1	5	1
1998	67	4	15	24	13	7	3	8	6	11	6	1	0	12	1
Sum	161	17	37	60	27	20	4	13	8	20	7	5	1	31	3

Pooling them together will become our research database for terminated alliances, which consists of 161 alliances From the table we can see that the three most frequent ingredients among terminated alliances are Code-sharing (C03), Joint FFP (C02) and Joint Operations (C13), while the three least frequent ingredients are IT Co-operation (C12), Commercial Agreement (C14) and Joint Purchasing (C06)

Similarly, five queries were used to generate five sub-databases of these alliances that were formed in different years and are still active in 1998 Again pooling these sub-databases together leads to our research database for lasting alliances, which has 297 alliances captured

Table 3: Lasting Alliances Formed in Different Years & Frequencies of Ingredients[1]

Year	Total	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14
Before 1995	149	16	33	82	28	18	4	26	13	7	18	0	3	34	2
1995	46	3	11	28	10	5	0	9	4	4	2	1	3	3	0
1996	35	6	6	29	6	2	0	2	2	3	2	1	0	0	1
1997	67	4	30	55	10	20	0	20	17	20	0	0	4	3	2
Sum	297	29	80	194	54	45	4	57	36	34	22	2	10	40	5

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[1] More accurately speaking, this database consists of two types of alliances the truly lasting ones that were formed before 1995 (about half of them in the database) and the teething ones that were formed after 1995 and are still subject to the test of time Therefore, strictly speaking, the results from analyzing the database of lasting alliances should be either the tested features or the emerging trends

Among the lasting alliances, Code-share (C03) is the most popular ingredient, followed by Joint FFP (C02) and Ground Support (C07) And Franchise/Royalty (C11) is the least frequent component, followed by Joint Purchasing (C06) and Commercial Agreement (C14)

3.   Distinct Features of Lasting and Non-lasting Alliances

3.1   Application of Exploratory Factor Analysis

It is well known that the primary goal of factor analysis, as one of multivariate techniques, is to define the underlying structure in a data set, represented by a few factors Factor analysis attempts to identify the common factor that is responsible for the correlation among the individual variables and subsequently estimate the pattern and the structure loadings, communalities, shared variances and the unique variances There are two types of factor analysis exploratory and confirmatory. The main difference between the two is the amount of *prior knowledge* on the factor structure As we actually know very little about the underlying pattern in alliance formation process, an exploratory factor analysis is more appropriate than a confirmatory factor analysis and will be used in this study

There are a number of factor extraction methods for exploratory factor analysis. Two commonly used ones are the Principal Component Factoring (PCF) and the Principal Axis Factoring (PAF) In PCF, it is assumed that the initial estimates of the communalities for all variables are equal to one and that the correlation matrix with the estimated communalities in the diagonal is subjected to the principal component analysis This implicitly assumes that there are no unique factors PAF, on the other hand, implicitly assumes that a variable is composed a common part and a unique part, and the common part is due to the presence of the common factors In other words, the PAF technique assumes an explicit factor model [2] With these considerations in mind, we decide to apply PAF as the factor extraction method for models that follow

Another technical issue in performing factor analysis is the choice of a factor rotation method Since factors under oblique (non-orthogonal) rotation method are usually difficult to interpret, we will use Varimax rotation method in our analysis, which is the most commonly used orthogonal rotation method in factor analysis The main advantage of Varimax method is its ability to generate a factor structure that results in each factor representing a distinct construct, which usually makes the naming of a factor much easier

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[2] For more information on factor analysis please refer to Sharma (1996) and Hair, et al (1995)

It is also important to mention that we need to make sure that the data are appropriate for factor analysis Two measures are commonly used The first one is the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which assesses the extent to which variables of construct belong together And the other one is the Barrlett test of sphericity, which is a statistical test to assess whether or not the correlation matrix is appropriate for factoring Bartlett test examines the extent to which the correlation matrix departs from orthogonality Both measures are available from computer printout if certain options are chosen Due to special structure of data (consisting of only 0s and 1s) and highly expositional nature of the study, it is sensible that as long as the data structure has some positive support by one of the two measures, we should go ahead with the analysis

3.2 Factor Analysis for Lasting Alliances

There are 297 lasting alliances in our database Beginning with the appropriateness test on the data, we find that the value of KMO measure is 0 641 and the Bartlett test statistic is highly significant ($p < .000$) This implies that the correlation matrix is not orthogonal and is, therefore appropriate for factoring

Table 4: Rotated Factor Loading for Lasting Alliances

		Factor					
		1	2	3	4	5	6
Equity	C01	0 074	0 004	**0.575**	0 059	-0 095	0 037
Joint FFP	C02	**0.587**	0 218	0 064	0 100	0 116	0 113
Code-sharing	C03	0 073	**0.769**	0 004	0 227	**0.414**	-0 071
Block seat & space	C04	-0 177	0 018	-0 098	**-0.715**	0 123	-0 032
Joint marketing	C05	**0.651**	0 079	0 327	0 037	0 009	0 160
Joint purchasing	C06	0 102	-0 018	0 066	0 011	0 030	**0.572**
Ground support	C07	**0.543**	0 014	0 187	0 122	-0 103	0 310
Airport facilities sharing	C08	**0.561**	0 103	-0 216	0 134	0 092	0 177
Flight scheduling	C09	**0.633**	0 071	0 033	0 007	0 035	-0 181
Pool agreements	C10	-0 119	**-0.577**	0 112	0 213	0 162	-0 067
Franchise/ royalty	C11	-0 035	-0 068	-0 037	-0 005	-0 025	0 009
IT co-operation	C12	0 185	0 086	**0.626**	0 013	0 020	0 152
Joint operations	C13	-0 077	-0 093	0 091	0 118	**-0.631**	-0 036
Commercial agreement	C14	-0 070	-0 022	0 090	0 019	-0 007	-0 024

Notes

(1) Extraction Method Principal Axis Factoring

(2) Rotation Method Varimax with Kaiser Normalization

(3) The cut-off value for significant factor loadings (at 5%) is about 0 33 [3]

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[3] Refer to Hair et al (1995 p 384) for a rough guide In our case here, the sample size is 297

We now start to interpret the final rotated factor loadings matrix (Table 4) The factor analysis has identified six significant factors The first factor is a *comprehensive one* involving five ingredients, the second, third and fifth factors contain two ingredients emphasizing complementary properties of the two; and fourth and sixth factors have one ingredient each suggesting the need for some specially arranged collaborations It is worthwhile to mention that only one ingredient appears more than once in these six factors, which is the code-sharing that is part of Factors 2 and 5.

The most prominent factor for lasting alliances is, of course, the leading factor that contains five significant ingredients, which, according to their relative importance, are joint marketing, flight scheduling, joint FFP, sharing airport facilities, and ground support In fact, this factor uncovers a very distinct feature of lasting alliances, that is, targeting at **customer brand loyalty and operations integration** These five ingredients together can lead to multilateral global alliances This factor resembles strikingly well to the ingredients of the Star Alliance [4]

The second factor indicates that code-sharing alliances, supported by pool agreements in revenue and costs, will be long lasting Any agreement involving revenue or/and cost needs serious trust and commitment between partners These two ingredients together usually lead to bilateral alliances due to the complication of pool agreements when involving more than two partners Therefore, this factor reveals the following feature of lasting alliances. **bilateral code-sharing alliances with financial trust and commitment tend to last long**

For the rest of the four factors, we can provide the following interpretation in relation to lasting alliances [5]

- Information technology co-operation and equity interest should be bound together A possible explanation is that IT initiatives usually lead to high financial returns Therefore, willing partners should offer a cross equity position as an incentive to participate and to ensure the success of IT co-operations (Factor 3)

- The sustainability of joint services/flight agreements will be enhanced if partners already have or are willing to have code-sharing agreement Alternatively speaking

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[4] The Star Alliance contains the following elements joint FFP (C02), joint airport lounges (part of C08), sharing of office space (part of C08), linking of flight schedules (C09) simplification of the ticketing procedures, melding of ground services (C07), sharing of sales decisions (part of C05), joint purchasing and co-location of airport facilities (part of C08)

[5] Unless really necessary, researchers rarely go beyond 4 factors, usually stop at three In our case, all factors are meaningful, a word of caution is that choosing the first four seems to the right thing to do

without code-sharing agreement, joint services/flights tend to be temporary (Factor 5)

· As long as proven mutually beneficial, specific alliances with a single ingredient in block seat/space arrangement and joint purchasing are still commonly used by active alliances (Factor 4 and Factor 6)

3.3 Factor Analysis for Non-Lasting Alliances

The database of non-lasting alliances consists of 161 alliances For the case of non-lasting alliances, KMO value is 0.441, which is usually classified as "unacceptable" [6] But the Bartlettt test shows that correlations exist at a significant level 000 Since the data have at least passed the Bartlett test, we now proceed the factor analysis

Using PAF extraction and Varimax rotation, we have a factor loadings matrix, as summarized in Table 5 below

Table 5: Rotated Factor Loading for Non-Lasting Alliances[7]

		Factor					
		1	2	3	4	5	6
Equity	C01	0 355	-0 036	-0 089	-0 090	0 046	0 043
Joint FFP	C02	0 198	0 013	-0 079	-0 054	-0 089	0.668
Code-sharing	C03	0 103	0.891	-0 144	-0 103	-0 114	-0 035
Block seat & space	C04	-0 005	-0 074	-0 112	-0 125	0.827	-0 100
Joint marketing	C05	0 137	0 083	-0 020	0.784	-0 077	0 090
Joint purchasing	C06	0.854	0 103	-0 029	-0 077	0 020	-0 002
Ground support	C07	0.486	-0 004	-0 033	0 053	-0 024	0 149
Airport facilities sharing	C08	-0 040	0 011	-0 004	-0 039	0 007	0 413
Flight scheduling	C09	0 017	-0 026	-0 057	0 080	-0 113	0 233
Pool agreements	C10	-0 012	-0 096	-0 048	-0 054	-0 099	-0 093
Franchise/ royalty	C11	-0 040	-0 174	-0 147	-0 054	-0 129	-0 147
IT co-operation	C12	0.591	0 057	0 020	0 122	-0 016	0 009
Joint operations	C13	-0 068	-0 110	0.857	-0 123	-0 122	-0 112
Commercial agreement	C14	-0 034	-0 067	-0 036	0 309	-0 017	-0 081

Notes

(1) Extraction Method Principal Axis Factoring

(2) Rotation Method Varimax with Kaiser Normalization

(3) The cut-off value for significant factor loadings (at 5%) is about 0 44 [8]

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[6] When researchers are encountered with the problem of "unacceptable" KMO values, a typical remedy is to eliminate few variables with low communalities until the KMO value reaches at an acceptable level (usually > 5) We decided not to pursue this option for two reasons The main reason is that we need to create results with the same basis as in the case of lasting alliances The other reason is that we are applying factor analysis for data reduction purpose

[7] The software has in fact suggested 7 factors Since the 7th factor contains no significant ingredient, so it is reported here

[8] Refer to Hair et al (1995, p 384) for a rough guide In our case here the sample size is 161

First of all, the results in Table 5 give a clear-cut factoring structure Furthermore, only the leading factor is a composite one, while all other factors involve a sole ingredient Note that the leading factor contains the following ingredients (according their relative importance) Joint Purchasing (C06), IT co-operation (C12), and Ground Support (C07) A distinct feature of this factor is that they are all **non-core activities** and **non-customer-oriented** This is in strong contrast with the leading factor for lasting alliances For the remaining factors, we can make the following comments.

- Alliances involving solely in code-sharing without other commitments are doomed to fail.

- In the absence of collaboration/co-operation in other areas, alliances through joint operations in services/flights or joint venture are fragile alliances or short-term in heart

- Among the non-lasting alliances, block seat/space agreements are perceived as short-term instruments

From the above discussions, we can see the clear differences between lasting and non-lasting alliances But there is one common feature between the two, which is that joint operations and block seat/space arrangements are usually short-term, which have therefore appeared in both the terminated ones and active ones We will end this section with the following summary:

Key Feature	Lasting & Active Alliances	Non-Lasting Alliances
Customer Loyalty	Present	Absent
Operations Integration	Present	Absent
Bilateral Code-share with trust	Present	Absent
Temporary Service Linkup	Present	Present

4. Validating the Results by a Logit Model

4.1 The Logit Model

Since the ultimate goal in alliance research is to get a better understanding on why airlines are linked up or broken up The combination of our two research databases, the lasting (and active) ones and terminated ones, provides us a unique opportunity to develop a predictive model for the failure, or success, of each alliance This joint database has 458 alliances Since all ingredients are binary/categorical variables, a logistic regression model is a natural choice to handle our problem That is, we are going to use the following model·

$$\ln \frac{p}{1-p} = \beta_0 + \beta_1 \cdot C01 + L \ \beta_{14} \cdot C14$$

where p is the probability that an alliance fails This can be re-written as follows

$$p = \frac{1}{1 + \exp(-(\beta_0 + \beta_1 \cdot C01 + L \ \beta_{14} \cdot C14))}$$

Ideally, we should use some variable selection procedure to find the 差est" model with least number of variables[9] But as we need to use the result of the logit model to validate findings from factor analysis, omitting any variable will undermine its ability to do so Therefore, we will just use the 妹ull" logistic regression model with all of 14 (categorical) variables included The edited outputs from the estimated logit model are summarized in Table 6

We can see that the significant variables in the Logit model (according to their actual level of Significance) are Code-sharing (C03), Ground Support (C07), Pool Agreements (C10), Joint Purchasing (C06), and Block Seat/Space Arrangements (C04) It is clear that only Joint Purchasing is elping" to *reduce* the probability of failure In the meantime, directly interpretation of the coefficient may not be meaningful

From Table 6, we see that as for the prediction accuracy, if the cut-off probability is 0 5, meaning that success and failure of a alliance are equally likely, the logit has predicted the lasting alliances correctly 87 21% of time, but predicted the non-lasting alliances correctly only 39 13% of time, with an overall accuracy of 70 31% If the sample probability is used, that is, 161/458 ≈ 0 35, the correct predictions for non-lasting alliances are improved to 58 39% and the correct prediction for lasting alliances are down do 74 75%, with an overall accuracy of 69% We will use the cut-off value of 0 35 for the validations that follow

Table 6: Fitted Logit Model

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[9] For more information on logistic regression. please refer to Chapter 10 of Sharma (1996)

```
-2 Log Likelihood        524.796

Classification Table for STATUS (1 = Terminated)
The Cut Value is .50
                Predicted
                0       1      Percent Correct
                0   I   1
Observed      +-------+-------+
   0      0   I 259 I  38  I    87.21%
              +-------+-------+   .
   1      1   I  98 I  63  I    39.13%
              +-------+-------+
                    Overall   70.31%


Classification Table for STATUS (1 = Terminated)
The Cut Value is .35
                Predicted
                0       1      Percent Correct
                0   I   1
Observed      +-------+-------+
   0      0   I 222 I  75  I    74.75%
              +-------+-------+
   1      1   I  67 I  94  I    58.39%
              +-------+-------+
                    Overall   69.00%


------------------ Variables in the Equation ------------------

Variable        B        S.E.    Wald      df    Sig      R       Exp(B)

C01(1)        -.0861    .3755    .0526      1   .8186   .0000    .9175
C02(1)        -.0027    .2904    .0001      1   .9926   .0000    .9973
C03(1)        1.4768    .2526   34.1813     1   .0000   .2328   4.3789
C04(1)         .7662    .3194    5.7562     1   .0164   .0795   2.1517
C05(1)        -.0176    .3654    .0023      1   .9616   .0000    .9826
C06(1)       -2.2982    .8779    6.8523     1   .0089  -.0904    .1004
C07(1)        1.3771    .4026   11.7011     1   .0006   .1278   3.9634
C08(1)         .7456    .4730    2.4849     1   .1149   .0286   2.1076
C09(1)        -.3667    .3724    .9701      1   .3247   .0000    .6930
C10(1)        1.5360    .5004    9.4215     1   .0021   .1118   4.6458
C11(1)        -.3320    .8770    .1433    . 1   .7050   .0000    .7175
C12(1)        1.6423   1.3105    1.5704     1   .2101   .0000   5.1669
C13(1)         .2887    .3244    .7917      1   .3736   .0000   1.3346
C14(1)         .8186    .7969    1.0554     1   .3043   .0000   2.2674
Constant     -4.9636   2.1975    5.1020     1   .0239
```

4.2   Validations of Leading Factors for Lasting and Non-lasting Alliances

Once a predictive model, such a logit model, is developed, it is possible to validate the leading (composite) factors derived from a factor analysis model   For this purpose, we will try to validate the first three factors from the factor analysis model for lasting alliances and one (and only one) leading factor from the factor analysis model for non-lasting alliances. The results of these validations are summarized in Table 7   It is not surprising to see positive validation for all of the leading factors

Table 5: Validation of Leading Factors from Factor Analysis

	Lasting Alliances	Terminated Alliances

Variables with Significant Factor Loadings	Leading Factors			Leading Factor
	1	2	3	1
Equity C01	0	0	1	0
Joint FFP C02	1	0	0	0
Code-sharing C03	0	1	0	0
Block seat & space C04	0	0	0	0
Joint marketing C05	1	0	0	0
Joint purchasing C06	0	0	0	1
Ground support C07	1	0	0	1
Airport facilities sharing C08	1	0	0	0
Flight scheduling C09	1	0	0	0
Pool agreements C10	0	1	0	0
Franchise/ royalty C11	0	0	0	0
IT co-operation C12	0	0	1	1
Joint operations C13	0	0	0	0
Commercial agreement C14	0	0	0	0
Calculated Probability	0 2402	0 0810	0 2745	0 4658
Classification (1 = Failure)[a]	0	0	0	1
Validated?	Yes	Yes	Yes	Yes

(a) The cut-off probability is 0 35, the sample probability of terminated alliances, i e , 161/458

5.   Conclusions

Most of previous works tend to focus on the ex post impact analysis by using traditional measurement methods, usually in profitability, costs and productivity. Event analysis models or other econometric models can be used for this purpose. In this paper, we have attempted to address the strategic alliance phenomenon in the airline industry from a different perspective Our aim is not on the impact of the alliances, rather to uncover any possible pattern on these characteristics that help alliances to sustain, in the meantime, to find the differences between the lasting alliances and non-lasting alliances

A factor analysis method was used to identify the underlying structures of alliances As for lasting alliances, a key distinct feature found to be the driving force for success is to aim for improvement in customer loyalty and facilitation in operations integration. Another feature is that to ensure the success of bilateral code-sharing, serious commitment and trust in pooling the revenue and/or cost will certainly help For non-lasting alliances, the two distinct features uncovered from factor analysis emerge first, alliances on non-core and non-customer activities will not survive very long, second, code-sharing agreements without serious commitment that will affect the bottom line are doomed to fail These findings are further validated by a logit model

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Appendix A: Initiating Airlines Used in This Study

Rank[a]	Airline (Code)	Passenger Carried
1	Singapore Airlines (SQ)	11,840,667
2	Swissair (SR)	8,825,789
3	Virgin Atlantic Airways (VS)	2,292,417
4	Ansett Australia (AN)	13,469,000
5	Cathay Pacific (CX)	10,885,084
6	British Airways (BA)	29,044,000
7	Qantas (QF)	7,114,620
8	EVA Air (BR)	N/A
9	Emirates (EK)	2,863,195
10	Lufthansa (LH)	33,116,407
11	All Nippon Airways (NH)	39,377,380
12	Air New Zealand (NZ)	2,932,672
13	KLM (KL)	12,928,075
14	SAS (SK)	19,681,769
15	SilkAir (MI)	N/A
16	Thai International (TG)	14,078,329
17	Japan Airlines (JL)	19,979,053
18	Lauda-Air (NG)	N/A
19	South African Airways (SA)	N/A
20	Air France (AF)	16,400,643
21	Royal Brunei (BI)	N/A
22	Northwest Airlines (NW)	52,682,000
23	United Airlines (UA)	81,863,000
24	Korean Air (KE)	20,877,541
25	Gulf Air (GE)	4,801,175
26	Malaysia Airlines (MH)	15,117,560
27	Canadian Airlines (CP)	8,578,019
28	Austrian (OS)	N/A
29	American Airlines (AA)	79,324,000
30	Air Canada (AC)	14,278,029
31	Asiana (OZ)	9,518,309
32	Dragonair (KA)	1,794,741
33	Varig (RG)	4,647,024
34	China Airlines (CI)	N/A
35	Delta (DL)	97,201,000
36	Continental (CO)	35,742,000
37	Air Mauritius (MK)	716,933
38	Alitalia (AZ)	23,138,000
39	Sempati (SG)	2,887,027
40	Philippine Airlines (PR)	5,641,356
41	Air Lanka (UL)	1,170,702
42	Pakistan International (PK)	2,756,635
43	Garuda Indonesia (GA)	6,841,447
44	Vietnam Airlines (VN)	N/A
45	Merpati (MZ)	3,190,595
46	Air-India (AI)	2,870,345
47	Indian Airlines (IC)	6,852,736
48	Biman Bangladesh (BG)	1,251,976
49	China Southern (CZ)	11,315,008
50	China Southern (MU)	6,104,262

(a) The Rank here is from 'The Leading Airlines – 1996', *Business Traveller Asia Pacific*, October 1996 Issue

Appendix B: Descriptions of Alliance Ingredients[10]

C01: Equity
- Taking up of shares in another carrier

C02: Joint FFP
- Self-explanatory.

C03: Code-sharing
- A marketing arrangement between airlines allowing them to sell seats on each other's flights under their own designator code In the case of connecting flight of two or more code-sharing carriers, the whole flight is displayed as a single carrier service on a computer reservation system.

C04: Block seat and space arrangements
- A contractual arrangement between two airlines, whereby a specified number of passenger seats or cargo space are allocated between more than two points on a carrier's route for a given period of time. The space swap agreement (usually as a side agreement of a code-share package) is also included here

C05: Joint marketing
- Self-explanatory, usually involving setting up of joint sales office

C06: Joint purchasing
- An arrangement where partners in the agreement buy things in bulk to enjoy economies of scale Examples include utensils, engine parts and etc

C07: Ground support
- Including ground handling, engineering, maintenance and cargo

C08: Airport facilities sharing arrangements
- Self-explanatory These facilities include passenger lounge, hangars, slots and other equipment in the airport.

C09: Flight scheduling
- Joint planning of flight schedule among carriers to minimize the transit time

C10: Pool agreements (revenues and costs)
- Agreement between two or more airlines to combine capacity operated. Tickets for the agreed sectors are used interchangeably without endorsement. Aspects include revenue pooling, revenue sharing and cost sharing

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[10] Most of the explanations here are taken and modified from Greoenewege (1996) Further clarifications are done through personal communication with Mr Karmjit Singh of Singapore Airlines As usual, I am responsible for any mis-interpretations

C11: Franchise/royalty
- The use of another airline colour/arrangements

C12: Information technology co-operation
- Linking of IT systems together

C13: Joint operations
- Including joint services/flight and business ventures A scheduled air service operated by an airline between points on its own behalf and that of another airline by sharing the costs and revenue on an agreed basis. Each carrier assigns its own airline code and flight number, which is both, displayed as a joint service.

C14: Commercial agreement
- Arrangement from one airline to another for use of certain traffic rights This arises because there is no reciprocity in the exchange or usage. For example, Country A may allow a carrier from Country B to operate to Country A even when its own carrier has no plans to operate to Country B. To facilitate this, a carrier from country B may agree to a commercial agreement with a carrier from Country A

Scheduling Decisions in an Airline Network: A Hub-and-Spoke System's Effect on Flight Frequency, Fares and Welfare

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Abstract

This paper provides a comprehensive economic analysis of scheduling decisions in an airline network. Although it is widely believed that the growth of hub-and-spoke networks has raised flight frequencies, the only analysis of this question is contained in a recent paper by Berechman and Shy (1998), who analyze an incomplete model. The present analysis shows that flight frequency is higher in a hub-and-spoke (HS) network than in a fully-connected (FC) network, confirming the conventional wisdom. It is also shown that some passengers who could make a connecting trip under the HS network may find the existing flights not sufficiently convenient given their long duration, thus choosing not to travel. By contrast, all passengers choose to travel under the FC network. The welfare analysis shows that the airline provides excessive flight frequency relative to the social optimum in both the FC and HS cases, and that its choice of network type exhibits an inefficient bias toward the HS network.

Scheduling Decisions in an Airline Network: A Hub-and-Spoke System's Effect on Flight Frequency, Fares and Welfare

by

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1. Introduction

Hub-and-spoke networks have become a central feature of airline operations in the post-deregulation era. By feeding passengers through hub airports, the airlines are able to concentrate their traffic on relatively few routes. This concentration raises traffic densities above the levels achieved under a point-to-point (or "fully connected") network, where all cities are connected by nonstop service. High densities in turn lead to lower operating costs via economies of traffic density, under which cost per passenger on an airline route falls as the density of traffic rises Economies of density result from the greater efficiency of larger aircraft and from better utilization of fixed facilities as traffic on a route expands. Spurred by the growth of hub-and-spoke (HS) networks, a substantial theoretical literature on the economics of airline networks has arisen, with economies of density being a key element of most models.[1]

Efficiency gains from HS operations have undoubtedly contributed to the decline in real airfares over the post-deregulation era, a decline that is documented by Morrison and Winston (1995) In addition, it is widely believed that the growth of HS networks has led to improvement in one element of service quality, namely flight frequency. While the need for hub-airport layovers tends to offset these frequency benefits for connecting passengers, it remains true that most passengers have a broader choice of arrival times than in the pre-HS era This fact is illustrated in data provided by the U S General Accounting Office (1999), which show that over the 1978-1998 period. the number of departures rose by 44 percent at small airports. by 58 percent at medium-size airports. by 83 percent at medium-large airports. and by 100 percent at large airports While the secular rise in traffic volumes may explain part of this increase in frequency, some portion of the increase no doubt reflects the impact of HS operations

If aircraft size and total network traffic were fixed, then the effect of an HS network ..

flight frequency would be transparent. Frequent flights would be required on each spoke route to accommodate the dense traffic flows in and out of the hub But aircraft sizes are chosen endogenously instead of being fixed, and total traffic may itself be influenced by frequency given that convenient service stimulates travel. These considerations suggest that the effect of network structure on flight frequency is less straightforward than it may first appear.

The purpose of the present paper is to provide a complete analysis of the scheduling issue showing how flight frequencies, fares, and social welfare differ between an HS network and a fully-connected (FC) network. The analysis extends the economics literature's only existing model of scheduling in networks, which is provided by Berechman and Shy (1998). As in Berechman and Shy, the present analysis focuses on the simplest possible network, which has three endpoint cities, one of which may serve as a hub. In addition, the model uses Berechman and Shy's assumption on airline costs, with each flight entailing a fixed cost but no passenger-related variable costs. Once flight frequency is determined, this cost structure generates economies of traffic density, as explained further below.

The analysis differs from that of Berechman and Shy in its treatment of pricing. In their model, an ad hoc specification relates utility to flight frequency, yielding passenger willingness-to-pay as a function of frequency. By contrast, the present analysis provides complete micro-foundations for passenger behavior. The model posits a distribution across passengers of desired arrival times, along with a utility function that depends negatively on schedule delay which equals the difference between the desired and actual arrival time. The monopoly airline sets fares and flight frequency taking account of this utility structure, recognizing that high fares or inconvenient, widely-space flight departures will result in a loss of traffic, as some potential passengers choose not to make a trip.

Using this setup, the analysis solves for the monopoly airline's optimal fares and flight frequencies under an HS network and an FC network, where nonstop service is provided between each pair of endpoint cities The airline's choices under the two network structures are then compared, and a key result is that flight frequency is higher under the HS network This result which also emerges in Berechman and Shy's analysis, confirms the conventional wisdom regarding the effect of network structure on flight frequency

To see the intuition behind this finding, observe that the airline satisfies a standard marginal condition in choosing the number of flights, f. In particular, the airline's marginal cost as a function of f is set equal to the fixed cost per flight. Marginal revenue, however depends on fares, which in turn depend on frequency. More flights lead to a smaller average schedule delay, allowing the airline to charge higher fares to some passengers. Taking these price effects into account, the airline chooses f optimally. The key difference between the HS and FC cases is that, for a given f, each flight contains *more passengers* in an HS network than in an FC network. Connecting passengers are present along with "local" passengers, who terminate or originate at the hub. Although separate fares are set for the two types of passengers, which introduces some added complexity, the greater number of passengers per flight in an HS network (for a given f) ultimately means that marginal revenue as a function of f is higher than in an FC network. This implies that the airline's marginal condition is satisfied at a higher value of f, yielding greater frequency in an HS network.

In addition to establishing this result, the analysis compares the fares charged in the two types of networks, and investigates which network type the airline will choose. A welfare analysis is then presented, where it is shown that within each type of network, the airline's frequency choice is inefficient. In addition, the profit-maximizing network type may be different from the one society prefers

Section 2 of the paper presents the basic model and analyzes the FC network. Section 3 analyzes the HS network, and compares the FC and HS solutions. Section 4 conducts the welfare analysis

2. Basic Model and FC Network Solution

2.1 Preliminaries

A monopoly airline serves three cities, A, B and H, as shown in Figure 1. Demand for travel exists between each pair of cities, yielding three city-pair markets: AH, BH and AB. While round-trip travel occurs in both directions in each market (i e , A to B and back B to A and back) the analysis focuses on the demand for one-way travel in a single direction in each market, recognizing that symmetric one-way trips occur in the other direction

In an FC network, the airline operates flights between each pair of cities, so that nonstop travel occurs in each city-pair market. In an HS network, the airline operates flights on only two routes, those connecting cities A and B to the hub H. Although passengers in markets AH and BH still enjoy nonstop service, AB passengers must make a two-segment trip, changing planes at the hub. Thus, flights in the HS network carry both local traffic (passengers in markets AH or BH) and connecting traffic (passengers in market AB).

Travel demand is identical in the three city-pair markets, and it is generated as follows. A passenger's utility u is equal to consumption expenditure plus trip benefits. Consumption expenditure equals income y minus the airfare p, while trip benefits are equal to a gross benefit δ minus the time costs of the trip. Time costs in turn depend on travel time and schedule delay, which measures the deviation between the desired and actual arrival times.[2] Utility is thus written

$$u \;=\; y \;-\; p \;+\; \delta \;-\; \alpha|t_a - t^*| \;-\; \beta h, \tag{1}$$

where h is travel time, t^* is the desired arrival time, and t_a is the actual arrival time. The parameter β gives the disutility per hour of travel time, while α gives disutility per hour of schedule delay.[3] Note that this disutility is symmetric between late and early arrivals. Utility in the absence of a trip is equal to income y.

In each city-pair market, desired arrival times are uniformly distributed on a circle of unit circumference, which represents the 24-hour clock. The density of passengers on the circle is equal to D. To discuss the airline's scheduling choice, consider the FC network, where the flights on a particular route carry passengers from a single city-pair market. The monopoly airline spaces its departures, and hence its arrival times, equally around the circle representing the desired arrival times of these passengers.[4]

The "market area" for each flight, which consists of the range of passengers it serves on the circle, depends on the fare the airline charges. For a given arrival time t_a, the smallest value of t^* for which a passenger finds a trip worthwhile satisfies

$$y \;-\; p \;+\; \delta \;-\; \alpha(t_a - t^*) \;-\; \beta h \;=\; y \tag{2}$$

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which indicates that the utility from the trip is equal to the utility from not travelling Solving (2) yields $t^* = (p + \beta h + \alpha t_a - \delta)/\alpha$. The number of passengers who find the flight worth taking is found by doubling the difference between t_a and t^* and multiplying by passenger density, which yields

$$2(t_a - t^*)D = 2D(\delta - p - \beta h)/\alpha. \tag{3}$$

However. passengers per flight can never exceed the total number of potential passengers divided by the number of flights, f Since the number of potential passengers equals D (recall the circle's unit circumference), it follows that this ratio equals D/f. Therefore, passengers per flight. denoted q, satisfies

$$q = \min\{\theta(\delta - p - \beta h), D/f\}, \tag{4}$$

where

$$\theta = 2D/\alpha. \tag{5}$$

To interpret (4). observe that if the airline charges a high fare, then relatively few passengers find the trip worth taking The number of passengers per flight is then less than largest possible number given f, which equals D/f. It follows that, when the fare is high, passengers with large schedule delays choose not to travel and are thus not served by the airline.

As noted above, the only costs incurred by the airline consist of a fixed cost per flight. denoted c While the absence of variable costs means that adding extra passengers to a flight is costless. a larger passenger load in reality requires operating a larger, more-expensive aircraft The assumed cost structure is therefore unrealistic. but it leads to a transparent model with simple solutions In addition, as explained further below, some properties of the solutions are unchanged when flight costs include both a fixed cost and variable costs

This cost structure ultimately has implications for the extent of economies of traffic density The strength of the density effect depends on the rate of decline of cost per passenger as total traffic on a route rises If all passengers are served, cost per passenger equals fc/D. which declines rapidly as total traffic D rises holding f fixed However. since the optimal f will rise

be a function of D, the strength of the density effect cannot be determined until the airlines optimization problem has been solved.

2.2. The optimization problem

To solve the airline's profit maximization problem under the FC network, recall that in this case. the airline serves each of the three city-pair markets AH, BH, and AB with separate flights. Total profit is therefore

$$\pi_{FC} = 3(fpq - fc), \tag{6}$$

where q is given by (4). The choice variables in this optimization problem are f, p, and q

To understand the problem's solution, it is useful to first proceed heuristically. Then a more systematic approach is presented The key observation is that the airline sets f and p so that all potential passengers are served and the fare is as high as possible given the value of f In other words, f and p are set so that $\theta(\delta - p - \beta h) = D/f$ holds, implying $p = \delta - \beta h - D/f\theta$ This outcome is illustrated in Figure 2, which shows the spacing of flights as well as their market areas. To see the reason for this choice, observe that charging a lower fare for given f would not boost traffic, which is already as large as possible. On the other hand, if a higher fare were charged. then some potential passengers would not be served. But if profit per flight for the existing flights is positive. it makes sense to add flights so that these passengers are served as well Since $q = D/f$ holds, revenue is then $3fpq = 3D(\delta - \beta h - D/f\theta)$, and profit as a function of f is

$$3D(\delta - \beta h - D/f\theta) - 3fc. \tag{7}$$

The optimal f can be found by simple maximization of (7), and p and q can be recovered from the above formulas The resulting solutions are discussed below.

Although this approach leads to the correct answer when the airline actually provides service. setting $f > 0$. it obscures the circumstances under which $f = 0$ is optimal A more systematic approach illuminates this issue while facilitating the analysis of the more-complex HS case in the next section This approach attacks the airline's optimization problem in

stages, solving first for the optimal p conditional on f, and then solving for the optimal f in the second stage

From (4), $q = D/f$ holds if $D/f < \theta(\delta - p - \beta h)$ or if $p < \delta - \beta h - D/f\theta$, with $q = \theta(\delta - p - \beta h)$ holding otherwise. Therefore, profit in (6) may be written as

$$\pi_{FC} = \begin{cases} 3fp\theta(\delta - p - \beta h) - 3fc & \text{if } p \geq \delta - \beta h - D/f\theta \\ 3Dp - 3fc & \text{if } p < \delta - \beta h - D/f\theta. \end{cases} \tag{8}$$

Holding f fixed, (8) gives π_{FC} as a function of p, with Figure 3 showing two different possibilities. For small p, π_{FC} is linearly increasing in p. Beyond $p = \widehat{p}(f) \equiv \delta - \beta h - D/f\theta$, profit is a quadratic function of p, but the function may assume several positions. Suppose that the slope of the quadratic at $p = \widehat{p}(f)$ is negative, which requires that the slope expression $\delta - 2p - \beta h$ evaluated at $p = \delta - \beta h - D/f\theta$ is negative. In this case, which requires $f > 2D/\theta(\delta - \beta h)$ the maximum of π_{FC} occurs at $p = \widehat{p}(f)$. On the other hand, if the quadratic slope is positive at $p = \widehat{p}(f)$, which requires $f < 2D/\theta(\delta - \beta h)$, then the maximum lies at the peak of the quadratic function, where $p = (\delta - \beta h)/2$. Letting $p^*(f)$ denote the optimal p conditional on f, it then follows that

$$p^*(f) = \begin{cases} (\delta - \beta h)/2 & \text{if } f < \overline{f} \\ \delta - \beta h - D/f\theta & \text{if } f \geq \overline{f}, \end{cases} \tag{9}$$

where

$$\overline{f} = 2D/\theta(\delta - \beta h) \tag{10}$$

Combining (9) and (4), the optimal q conditional on f is given by

$$q^*(f) = \begin{cases} \theta(\delta - \beta h)/2 & \text{if } f < \overline{f} \\ D/f & \text{if } f \geq \overline{f}, \end{cases} \tag{11}$$

It is easily seen from (10) and (11) that when $f < \overline{f}$, $q^*(f) < D/f$ holds, so that some passengers are not served. When $f \geq \overline{f}$, by contrast, all passengers are served.

Substituting (9) and (11) into (6) yields π_{FC} purely as a function of f.

$$\pi_{FC} = \begin{cases} 3f[\theta(\delta - \beta h)^2/4 - c] & \text{if } f < \bar{f} \\ 3D(\delta - \beta h - D/f\theta) - 3fc & \text{if } f \geq \bar{f}. \end{cases} \qquad (12)$$

Note that the profit expression in the second line of (12) is the same as the expression (7) derived previously. Using (12), the derivative of π_{FC} with respect to f is given by

$$\frac{\partial \pi_{FC}}{\partial f} = \begin{cases} 3[\theta(\delta - \beta h)^2/4 - c] & \text{if } f < \bar{f} \\ 3D^2/f^2\theta - 3c & \text{if } f \geq \bar{f}. \end{cases} \qquad (13)$$

Inspection of (13) shows that $\partial\pi_{FC}/\partial f$ is continuous, decreasing in f when f is above $\bar{f}$, and constant when f is below $\bar{f}$. The function π_{FC} is therefore concave, so that a point where its derivative is zero represents a global maximum. For such a point to exist, $\theta(\delta - \beta h)^2/4 - c$ in the first line of (13) must be positive, in which case the derivative becomes zero somewhere on the decreasing range represented by the second line. The optimal value is given by setting the second-line expression equal to zero and solving for f, which yields $f = D/\sqrt{c\theta}$. On the other hand, if $\theta(\delta - \beta h)^2/4 - c < 0$ holds, then $\partial\pi_{FC}/\partial f$ is everywhere negative, and the optimal f equals zero.

Let f_{FC}^* denote the optimal value of f under the FC network. After substituting $\theta = 2D/\alpha$ from (5) into the f solution and inequalities from the previous paragraph, the following conclusion may be stated:

$$f_{FC}^* = \begin{cases} 0 & \text{if } c \geq \bar{c}_{FC} \\ \sqrt{\alpha D/2c} & \text{if } c < \bar{c}_{FC}, \end{cases} \qquad (14)$$

where

$$\bar{c}_{FC} = D(\delta - \beta h)^2/2\alpha. \qquad (15)$$

The intuitive explanation for the two cases shown in (14) is straightforward. If the cost per flight c is larger than the critical value $\bar{c}_{FC}$, then the airline is better off providing no service

whatsoever, setting $f = 0$. Since this condition is harder to satisfy when $\bar{c}_{FC}$ is high, service is likely to be offered in this case. A high $\bar{c}_{FC}$ emerges, making service likely, when the trip benefit net of the cost of travel time $(\delta - \beta h)$ is large or when passenger density D is large. A small value of α, indicating a low disutility from schedule delay, also leads to a high $\bar{c}_{FC}$ making service likely. Finally, it should be noted that, because an interior solution must satisfy $f > \bar{f}$, it follows that all passengers are served under the FC solution, as mentioned above

The optimal flight frequency also depends on the model's parameters. From (14), frequency is high when the cost per flight is low. A large density D or a large disutility α from schedule delay also leads to high flight frequency. With the optimal f known, the extent of economies of traffic density can also be appraised. Cost per passenger, which equals fc/D, reduces to $\sqrt{\alpha c/2D}$ after substitution of f^*_{HS}. Since this expression is decreasing in D, economies of traffic density are present. But the increase in f as D rises means that the density effect is less strong than if flight frequency were fixed

Finally, substituting (14) into (9) yields the optimal fare, which is given by

$$
\begin{aligned}
p^*_{FC} &= \delta - \beta h - D/f^*_{FC}\theta \\
&= \delta - \beta h - \sqrt{\alpha c/2D} \quad\quad (16)
\end{aligned}
$$

Note that since the last term in (16) equals cost per passenger from above, the optimal fare equals trip benefit net of travel-time cost minus the airline's cost per passenger For profit to be positive. (16) must itself be larger than cost per passenger This inequality reduces to the requirement that c be less than the critical value in (15).

3. HS Network Solution

3 1 Preliminaries

Suppose that instead of operating an FC network, the airline operates an HS network In this case, passengers in the AB city-pair market must make a connecting trip through the hub H rather than travelling nonstop The time duration of this trip is assumed to equal $2h$

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that the trip takes twice as long as a nonstop trip. This assumption implies a zero layover time at the hub.

The fare for the connecting AB trip is denoted P, while p continues to denote the fare paid the passengers in the AH and BH markets. As in actual practice, the airline sets P independently of p. In other words, the connecting fare P is *not* the simple sum of the fares for the AH and BH segments of the connecting trip. The airline's fare choices are constrained however, by the arbitrage condition $2p \geq P$, which says that the connecting passenger cannot fly more cheaply by purchasing separate AH and BH tickets. Because this arbitrage condition is satisfied by the unconstrained solution, it is not imposed explicitly in the airline's optimization problem

Unlike in the FC case, passengers from two different city-pair markets share a given aircraft under the HS network. AH and AB passengers are commingled on flights between A and H while BH and AB passengers are commingled on flights between B and H. Despite this intermixing. the market area of a given flight is determined in the same way as before. Passengers in each of the two city-pair markets take the flight that allows them to arrive closest to their desired time, and for a given spacing of flights, a high fare in a particular market will lead some passengers not to travel.

The traffic level q in each of the "local" markets, AH and BH, is again given by (4). Parallel analysis yields the traffic level Q in the "connecting" market AB, which is given by

$$Q = \min\{\theta(\delta - P - 2\beta h), D/f\} \tag{17}$$

Note the presence of the multiplicative factor 2 in the travel-time element of (17), which reflects the longer time spent on a connecting trip

3.2 The optimization problem

The airline's profit from operating an HS network is equal to

$$\pi_{HS} = 2fpq + fPQ - 2fc \tag{18}$$

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Note that revenue comes from two local markets and one connecting market, and that costs are incurred for operation of flights on two rather than three routes (compare (6)). The airline chooses p, q, P, Q, and f to maximize (18) subject to (4) and (17).

The same analysis as in section 2 applies to the choice of p conditional on f. Using (1) the revenue term $2fpq$ in (18) can be rewritten as in (8):

$$2fpq = \begin{cases} 2fp\theta(\delta - p - \beta h) & \text{if } p \geq \delta - \beta h - D/f\theta \\ 2Dp & \text{if } p < \delta - \beta h - D/f\theta. \end{cases} \tag{19}$$

As a result, the optimal p and q conditional on f are again given by (9)–(11).

Similarly, revenue from the connecting market is given by

$$fPQ = \begin{cases} fP\theta(\delta - P - 2\beta h) & \text{if } P \geq \delta - 2\beta h - D/f\theta \\ DP & \text{if } P < \delta - 2\beta h - D/f\theta. \end{cases} \tag{20}$$

Repeating the analysis of section 2, the optimal P and Q conditional on f are then given by

$$P^*(f) = \begin{cases} (\delta - 2\beta h)/2 & \text{if } f < \tilde{f} \\ \delta - 2\beta h - D/f\theta & \text{if } f \geq \tilde{f} \end{cases} \tag{21}$$

and

$$Q^*(f) = \begin{cases} \theta(\delta - 2\beta h)/2 & \text{if } f < \tilde{f} \\ D/f & \text{if } f \geq \tilde{f}, \end{cases} \tag{22}$$

where

$$\tilde{f} = 2D/\theta(\delta - 2\beta h). \tag{23}$$

Note that the only difference between (21) and (22) and $p^*(f)$ and $q^*(f)$ from (9) and (11) is that the travel-time term is $2\beta h$ instead of βh. This difference also implies that $\tilde{f} < \hat{f}$ (compare (23) and (10)).

Referring to (11) and (22), the cases where passengers are or are not served can be categorized. When $f < \tilde{f}$, both $q^*(f)$ and $Q^*(f)$ are less than D/f, and some local as well as

connecting passengers are not served. When $\bar{f} \leq f < \tilde{f}$, all local passengers are served, but some connecting passengers are not. When $f \geq \tilde{f}$, all passengers are served

To write profit as a function of f, (9), (11), (21), and (22) are substituted into (18) This yields

$$\pi_{HS} = \begin{cases} f[\theta(\delta - \beta h)^2/2 + \theta(\delta - 2\beta h)^2/4 - 2c] & \text{if } f < \bar{f} \\ 2D(\delta - \beta h - D/f\theta) + f\theta(\delta - 2\beta h)^2/4 - 2fc & \text{if } \bar{f} \leq f < \tilde{f} \quad (24) \\ 2D(\delta - \beta h - D/f\theta) + D(\delta - 2\beta h - D/f\theta) - 2fc & \text{if } f \geq \tilde{f}. \end{cases}$$

Using (24), the derivative of π_{HS} with respect to f is given by

$$\frac{\partial \pi_{HS}}{\partial f} = \begin{cases} \theta(\delta - \beta h)^2/2 + \theta(\delta - 2\beta h)^2/4 - 2c & \text{if } f < \bar{f} \\ 2D^2/f^2\theta + \theta(\delta - 2\beta h)^2/4 - 2c & \text{if } \bar{f} \leq f < \tilde{f} \quad (25) \\ 3D^2/f^2\theta - 2c & \text{if } f \geq \tilde{f}. \end{cases}$$

Inspection of (25) shows that $\partial \pi_{HS}/\partial f$ is continuous, constant for $f < \bar{f}$, and decreasing in f for $f > \bar{f}$ The profit function is thus concave, so that a stationary point again represents a global maximum As before, an interior maximum will not exist unless the first line of (25) is positive If this condition holds and $\partial \pi_{HS}/\partial f$ evaluated at $f = \tilde{f}$ is negative, then the optimal f lies between $\bar{f}$ and $\tilde{f}$. If $\partial \pi_{HS}/\partial f$ is instead positive at $f = \tilde{f}$, then the optimal f lies above $\tilde{f}$ From (25), $\partial \pi_{HS}/\partial f$ is negative (positive) at $\tilde{f}$ as $3\theta(\delta - 2\beta h)^2/4 - 2c < (>) 0$. In each case, the optimal f is found by setting the relevant line of (25) equal to zero.

Calculating these optimal values, and substituting for θ in the resulting expressions using (5). the following conclusion may be stated.

$$f^*_{HS} = \begin{cases} 0 & \text{if } c > \bar{c}_{HS} \\ \dfrac{1}{\sqrt{1 - D(\delta - 2\beta h)^2/4\alpha c}} \sqrt{\alpha D/2c} & \text{if } \tilde{c} < c \leq \bar{c}_{HS} \quad (26) \\ \sqrt{3/2}\sqrt{\alpha D/2c} & \text{if } c \leq \tilde{c}. \end{cases}$$

where

$$\bar{c}_{HS} = (D/\alpha)[(\delta - \beta h)^2/2 + (\delta - 2\beta h)^2/4] \quad (27)$$

$$\tilde{c} = (3D/4\alpha)(\delta - 2\beta h)^2 < \bar{c}_{HS} \quad (28)$$

Note that $c > \tilde{c}_{HS}$ implies that the first line of (25) is negative, and that (28) is derived from the inequality in the previous paragraph

Recalling that $\sqrt{\alpha D/2c}$ equals the interior f_{FC}^* solution from (14), the first conclusion to be drawn from (26) is that $f_{HS}^* > f_{FC}^*$ always holds when both solutions are positive. This follows because $\sqrt{3/2} > 1$ and because the expression inside the square root in the second line of (26) is between zero and one when $\tilde{c} \leq c$, making the reciprocal term greater than one In addition, since $\tilde{c}_{HS}$ exceeds $\tilde{c}_{FC}$ from (15), it follows f_{HS}^* is still positive over part of the range where f_{FC}^* is zero. Therefore,

$$f_{HS}^* > f_{FC}^* \tag{29}$$

holds whenever both variables are nonzero

Another important conclusion, which follows from the fact that an interior solution must have $f > \bar{f}$, is that all local passengers are served. All connecting passengers are served as well when $f_{HS}^* \geq \tilde{f}$, which requires $c \leq \tilde{c}$. However, some connecting passengers are not served when $\bar{f} < f_{HS}^* < \tilde{f}$, which requires $\tilde{c} < c < \tilde{c}_{HS}$ The latter case is illustrated in Figure 4 which shows that the market areas for connecting passengers do not fully cover the circle.

In addition, local passengers pay a higher fare in the HS network than in the FC case This follows because the same formula gives the local fare under both networks, a consequence of all passengers being served in both cases Thus,

$$p_{HS}^* = \delta - \beta h - D/f_{HS}^*\theta, \tag{30}$$

and comparing (16). the conclusion

$$p_{HS}^* > p_{FC}^* \tag{31}$$

follows from (29) By contrast, an ambiguous relationship exists between P^*, the fare paid by connecting passengers under the HS network and p_{FC}^* the nonstop fare they pay under

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FC network The HS network could lead to a higher or lower fare for such passengers But it can be verified that the arbitrage condition $2p^*_{HS} \geq P^*$, which was discussed above, holds at the optimum.[5]

Summarizing the above conclusions yields

Proposition 1. *Flight frequency is higher in a hub-and-spoke (HS) network than in a fully-connected (FC) network. However, the fare for connecting passengers may be high enough that some choose not to travel Local passengers pay a higher fare under the HS network, but the fare paid by connecting passengers could be higher or lower than in the FC network.*

3 3 Discussion

The intuitive explanation for higher flight frequency under the HS network, which was sketched above, is best seen by focusing on the case where all passengers are served, comparing the profit expressions in the last lines of (12) and (24). Observe that the airline's goal is, in effect, to maximize profit per route under both network structures. In the FC case, this means maximizing revenue per route, $D(\delta - \beta h - D/f\theta)$, minus cost per route, or fc. In the HS case, revenue per route includes the same term, which represents local passengers, but it also includes the added term $\frac{1}{2}D(\delta - 2\beta h - D/f\theta)$, which represents *half* the revenue from the connecting passengers Since revenue per route includes this extra term, marginal revenue per route as a function of f is higher in the HS network over the relevant range. From the last lines of (13) and (25), the relevant expressions are $\frac{3}{2}D^2/f^2\theta$ in the HS case and $D^2/f^2\theta$ in the FC case With marginal revenue higher under the HS network, the optimality condition is satisfied at larger value of f.

Because local passengers are always fully served under the HS network, as they are in the FC case, the marginal revenue expressions always share a common term under both network structures regardless of the level of f Therefore, even though the contribution of connecting passengers takes a different form when f is low and these passengers are not fully served marginal revenue remains higher under the HS network, leading to greater flight frequency

The flight-frequency result thus depends critically on the fact that local passengers are fully served under both network structures [6] An understanding of this outcome, as we

the possibility of incomplete service for connecting passengers, is therefore needed For the reasons explained above, it never makes sense to leave passengers of both types unserved If profit is earned in doing so, it can be raised by adding flights. Suppose then that both types of passengers are initially served, with each type charged the highest possible fare for the given f. Could there be gains from raising the fare for one type so that some passengers of this type choose not to travel? To see the answer, note that as price is raised, revenue is given by $p(\delta - p - \beta h)$ for local passengers and $P(\delta - P - 2\beta h)$ for connecting passengers, with marginal revenue as a function of the fare given by $\delta - 2p - \beta h$ and $\delta - 2P - 2\beta h$ in the two cases To investigate the incentive for raising fares, these MR functions can be evaluated at the fare levels consistent with full service, namely $p = \delta - \beta h - D/f\theta$ and $P = \delta - 2\beta h - D/f\theta$. After substitution, the MR expressions are $-\delta + \beta h + 2D/f\theta$ for local passengers and $-\delta + 2\beta h + 2D/f\theta$ for connecting passengers. The key observation is that marginal revenue for connecting passengers is larger. Therefore, even though MR is smaller for these passengers for a *common* fare level (see the earlier expressions), the fare consistent with full service is so much lower for connecting passengers (who require a greater inducement to travel given the longer trip) that their MR expression ends up being larger. Therefore, the incentive to raise the fare, which leads some passengers not to travel, is greater for connecting than local passengers If the cost per flight is relatively small (below $\tilde{c}$), the resulting nonprovision of service is ultimately not optimal for the airline, which finds it preferable to raise flight frequency so that all passengers are served But if $c > \tilde{c}$, this adjustment is too costly, and service is not provided to some connecting passengers.

Turning to the fare comparisons across network types, the reason why the local fare is higher under the HS network is that higher frequency shrinks the potential market area for each flight, which allows the local fare to be raised without loss of traffic Although potential market areas also contract in the HS case for connecting passengers, the longer HS travel time tends to shrink the size of each flight's actual market area by reducing the attractiveness of travel Therefore, the change in the fare that is required to make actual market areas fit inside the potential areas is unclear

3.4 Choice of network type

So far, the characteristics of the two types of networks have been analyzed without asking which type of network will actually be chosen The airline makes this choice by comparing profit levels in the FC and HS cases. To rule out uninteresting comparisons, c is assumed to be low enough so that service is provided under both network types This requires $c < \bar{c}_{FC}$ and $c < \bar{c}_{HS}$, but since $\bar{c}_{FC} < \bar{c}_{HS}$ holds from above, only the first inequality is needed For simplicity, c is also assumed to be sufficiently small that the airline serves all passengers under the HS network, which requires $c < \tilde{c}$. Since a comparison of (15) and (28) shows that the relation between $\bar{c}_{FC}$ and $\tilde{c}$ is ambiguous, simultaneous satisfaction of both the above inequalities requires $c < \min\{\bar{c}_{FC}, \tilde{c}\}$.

Imposing the above restriction, and substituting p^*_{FC} and f^*_{FC} from (14) and (16) into the profit expression (6), FC profit is equal to

$$\pi_{FC} = 3D\left(\delta - \beta h - 2\sqrt{\alpha c/2D}\right). \tag{32}$$

Similarly, substituting f^*_{HS} from the last line of (26) into (18) along with the relevant p^*_{HS} and P^* solutions, profit under the HS network is

$$\pi_{HS} = 3D\left(\delta - 4\beta h/3 - 2\sqrt{2/3}\sqrt{\alpha c/2D}\right). \tag{33}$$

Manipulating (32) and (33), it follows that

$$\pi_{HS} > (<) \ \pi_{FC} \quad \text{as} \quad \Omega\sqrt{\alpha c/2D} > (<) \ \beta h, \tag{34}$$

where

$$\Omega = 4\left(3/2 - \sqrt{3/2}\right) \tag{35}$$

Thus, the airline tends to form an HS network when α and c are large and when βh and D are small The intuitive reasons for these effects are discussed in the welfare analysis presented in the next section

4. Welfare Analysis

Two questions need to be answered in a welfare analysis. First, does the airline provide the socially-optimal flight frequency, conditional on network choice? Second, does the airline choose the socially-optimal network type? To analyze both questions, society's welfare function must be specified. The appropriate function equals gross trip benefits minus passenger time costs minus the costs incurred by the airline. This function is the same as aggregate utility plus airline profit, except for the absence of a constant term involving y.

It should be noted that, like the airline, the planner will not provide service under a given network type (setting $f = 0$) when the cost per flight c is sufficiently high. In addition, when HS service is worthwhile, the planner may follow the airline in not providing service to some connecting passengers, an outcome that emerges when c is relatively high. The critical values of c demarcating these various outcomes can be derived in a fashion similar to that followed above for the airline. Since the critical values differ between the planner and the airline, many different combinations of actions for the two entities are possible, depending on the value of c. To keep the analysis manageable, c is constrained so that the planner and the airline take the same type of action under each network type. In particular, c is assumed to be low enough so that both the airline and planner (i) choose to provide service under the FC network, and (ii) choose to provide service under the HS network, and to do so for all passengers. The relevant restriction on c is discussed below.

Aggregate time costs are a component of the social welfare function, and to compute these costs, the average schedule delay incurred by passengers must be derived. To generate this value, observe that the average difference between the desired and actual arrival times equals one quarter of the market area of a flight, which equals $1/4f$ under full service (recall that market area extends on both sides of the flight location). Aggregate schedule-delay costs are then $\alpha D/4f$ for each city-pair market. Adding the disutility of travel time and airline costs and then subtracting this total from aggregate trip benefits, the welfare function under the FC network is

$$w_{FC} = 3D\delta - 3D(3h + \alpha/4f) - 3fc \qquad (3)$$

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Under the HS network, the welfare function is

$$w_{HS} = 3D\delta - 2D(\beta h + \alpha/4f) - D(2\beta h + \alpha/4f) - 2fc. \qquad (37)$$

Note that the second and third terms in (37) represent time costs for local and connecting passengers respectively, assuming that all connecting passengers are served.[7] Choosing f to maximize (36) and (37) gives the socially optimal flight frequencies under the FC and HS networks, which equal

$$f_{FC}^{**} = \sqrt{1/2}\sqrt{\alpha D/2c}, \qquad f_{HS}^{**} = \sqrt{3/4}\sqrt{\alpha D/2c}. \qquad (38)$$

A first observation from (38) is that the planner chooses a higher flight frequency in the HS network than in the FC network, following the behavior of the airline. To compare the choices of the planner and the airline within a given type of network, (38) can be compared to the previous solutions for f_{FC}^{*} and f_{HS}^{*}. Comparing (38) and (14), it follows that $f_{FC}^{*} > f_{FC}^{**}$ holds, so that the airline chooses a higher flight frequency than the planner under the FC network. Comparing (38) and the last line of (26), the same conclusion emerges under the HS network $f_{HS}^{*} > f_{HS}^{**}$ holds. so that the airline again chooses a higher frequency than the planner

Thus. in both types of networks, the airline offers excessive flight frequency relative to the social optimum. The intuitive explanation is that, because greater frequency shrinks the potential market area of each flight, it allows the airline to raise fares without losing traffic. While this enhances the airline's profit, the higher fare revenue is simply a transfer between passengers and the airline. As a result, the fare-based impulse for higher frequency does not serve society's interest.

To investigate the second welfare question, namely the efficiency of the airline's network choice. the planner's criterion for choosing the network type must be developed and compared to the airline's criterion. This is done by substituting the optimal flight frequencies f_{FC}^{**} and f_{HS}^{**} into the welfare functions (36) and (37). which yields the first-best welfare levels ,

and w_{HS}^{**}. Manipulating the resulting expressions, it follows that

$$w_{HS}^{**} \; > \; (<) \; w_{FC}^{**} \quad \text{as} \quad \Phi\sqrt{\alpha c/2D} \; > \; (<) \; \beta h. \tag{39}$$

where

$$\Phi \; = \; 2\sqrt{2}\left(3/2 - \sqrt{3/2}\right) \; < \; \Omega. \tag{40}$$

The relevant network-choice criterion for the airline is (34), which is based on the maintained assumption of full service under the HS network. Noting that the left-hand sides of (34) and (39) differ, it follows that the airline's network choice is inefficient. To see the direction of the inefficiency, observe that the Φ term in (40) is less than the Ω term in (34) given $2\sqrt{2} < 4$. This difference means that airline chooses the HS network *more readily* than the society. In other words, under some conditions when society, choosing frequency optimally, would select the FC network (with the second inequality holding in (39)), the airline will instead choose the HS network (with the first inequality holding in (34)). Thus the airline's network choice exhibits an inefficient bias toward the HS network.

Although the intuitive reason for this result is not transparent, the common form of the conditions (34) and (39) has an appealing intuitive explanation. The conditions show that the HS network is favored when cost per flight c is large, a consequence of the fact that HS operations economize on total flights.[8] In addition, a large disutility α from schedule delay also favors the HS network, whose greater flight frequency reduces such delay. Conversely, if the total disutility βh from travel time is large, because of a large magnitude for either the utility parameter β or the travel time h, then the FC network is favored. The reason is that the nonstop travel pattern under the FC network minimizes travel time. Finally, a high passenger density D makes the traffic-collection role of the HS network less valuable, thus favoring the FC network.

Unfortunately, the planning solution is impractical to implement because it generally requires that fares equal zero, consistent with the zero variable cost per passenger.[9] Given this impracticality, it is useful to consider a second-best welfare analysis. The second-best approach

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recognizes that, in the current regulatory environment, flight-frequency and pricing decisions are made by the airline. The remaining decision is then choice of network type, and it can be asked whether the airline makes this choice in a socially-optimal fashion, conditional on its inefficient flight frequencies.

To answer this question, again assuming full service is provided in the HS case, the profit-maximizing flight frequencies, f_{FC}^* and f_{HS}^*, are substituted into the welfare functions given by (36) and (37). This yields the second-best welfare levels, w_{FC}^* and w_{HS}^*. Manipulating the resulting expressions, it follows that

$$w_{HS}^* > (<) \; w_{FC}^* \quad \text{as} \quad \Gamma\sqrt{\alpha c/2D} > (<) \; \beta h, \tag{41}$$

where

$$\Gamma = 3\left(3/2 - \sqrt{3/2}\right) < \Omega. \tag{42}$$

Since Γ is less than Ω from (34), the verdict on network choice is the same as in the first-best case. The airline will choose the HS network under some circumstances when the FC network would yield higher welfare, conditional on the profit-maximizing choice of flight frequency. Thus, the second-best network choice exhibits an inefficient bias toward the HS network, as in the first-best case.

A final question concerns the effect of network choice on passenger utility, again in a second-best setting. The answer is that passengers are worse off on average under the HS network than under the FC network, again assuming full service in the HS case. Substituting the average schedule delay $1/4f_{FC}^*$ along with p_{FC}^* into the utility expression (1), average passenger utility under the FC network reduces to

$$v_{FC}^* = y + (1/2)\sqrt{\alpha c/2D}. \tag{43}$$

Making analogous substitutions to compute average utility of both local and connecting passengers under the HS network (assuming under full service) it turns out that their ave .

utilities are equal and given by

$$v_{HS}^* = y + (1/\sqrt{6})\sqrt{\alpha c/2D} < v_{FC}^*.$$ (44)

Thus, passengers are always worse off under the HS network, an outcome that obtains even when the second-best welfare level is higher in the HS case. In this situation, higher airline profit more than offsets the reduction in passenger utility.

To understand why $v_{HS}^* < v_{FC}^*$ holds, observe first that the gross trip benefit δ and the disutility of travel time β do not appear in (43) and (44). Changes in these parameters are thus fully capitalized in fares, leaving utility unaffected. Average schedule delay also affects fares, but it can be shown that improvements in average delay are *overcapitalized*, so that the benefits of greater flight frequency under the HS network are more than offset by an increase in fares. The result is lower average utility under the HS case.[10]

Summarizing the above results yields

Proposition 2. *Suppose that cost per flight is low enough that the airline would serve all passengers if it operated an HS network. Then, under both the FC and HS networks, the airline chooses flight frequencies that are excessive relative to the socially-optimal levels. In addition, the airline's network choice exhibits an inefficient bias toward the HS network. This bias still emerges in a second-best setting, where the planner relinquishes control of flight frequency. In this second-best case, passenger utility is always lower under the HS network.*

5. Conclusion

This paper has provided a comprehensive analysis of scheduling decisions in an airline network. Although it is widely believed that the growth of hub-and-spoke networks has raised flight frequency, the only analysis of this question is contained in a recent paper by Berechman and Shy (1998) who analyze an incomplete model. The present analysis shows that flight frequency is indeed higher in a hub-and-spoke network than in a fully-connected network, confirming the conventional wisdom. The analysis also shows that some passengers who could make a connecting trip under the HS network may find the existing flights not sufficiently convenient given their long duration thus choosing not to travel. By contrast, all passenger

choose to travel under the FC network. Welfare analysis shows that the airline provides excessive flight frequency relative to the social optimum, and that its choice of network type exhibits an inefficient bias toward the HS network.

One drawback of the present analysis is that it assumes an unrealistic cost structure, with the airline incurring fixed flight costs but no passenger-related variable costs. Suppose instead that cost per flight were given by $c + \eta q$, where η is variable cost per passenger. Repetition of the analysis of sections 2 and 3 for this cost structure reveals a number of conclusions. First, if all passengers are served, then the presence of variable costs has no effect on flight frequency. The reason is that total costs are then $3fc + 3\eta D$ in the FC case and $2fc + 4\eta D$ in the HS case, so that the first-order conditions for f do not involve η. The intuitive reason is that when all passengers are served, variable costs reduce to a constant term that depends on D whose presence has no effect on the optimal f.

By contrast, if some connecting passengers are not served under the HS network, as may occur in the modified model, then marginal cost as function of f depends on η. The reason is that because more flights lead the airline to carry more connecting (and thus more total) passengers, variable costs rise with f at a rate that depends positively on η. The upshot is that, when some passengers are not served under the HS network, an increase in η leads to a reduction in flight frequency. This conclusion suggests that, in circumstances where the airline's traffic is elastic, stronger economies of density (corresponding to a lower η) lead to more-frequent flights, as intuition might suggest. However, this effect is absent when full service causes total traffic to be fixed.

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Footnotes

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[1]The contributions to this literature include Spiller (1989), Bittlingmayer (1990), Brueckner and Spiller (1991), Berechman, Poddar and Shy (1994), Zhang and Wei (1993), Hendricks. Piccone and Tan (1995, 1997), Oum, Zhang and Zhang (1995), Nero (1996), Zhang (1996) Park (1997). Brueckner (1997), Berechman and Shy (1998), Nero and Black (1998). Schipper. Nijkamp and Rietveld (1998a,b), and Pels, Nijkamp and Rietveld (1998). For an analysis of hub-and-spoke networks from an operations-research perspective, see Lederer (1993a.b) Empirical evidence on economies of density is provided by Caves, Christensen and Tretheway (1984), Brueckner, Dyer and Spiller (1992), and Brueckner and Spiller (1994).

[2]The concept of schedule delay is widely used in the literature on road pricing (see, for example, Arnott, de Palma and Lindsey (1990)).

[3]Since the focus is on one-way trips, the benefit parameter δ represents *half* the benefit of a round-trip journey. Similarly, y represents half of the income earned during the period covered by the trip.

[4]For other analyses of airline scheduling on a circular time domain, see Schipper. Nijkamp and Rietveld (1998a,b).

[5]When all connecting passengers are served, the fare they pay is equal to $P^* = \delta - 2\beta h - D/f^*_{HS}\theta$. For the arbitrage condition $2p^*_{HS} \geq P^*$ to hold, this expression must not be greater than twice (30). This condition reduces to $\delta - D/f^*_{HS}\theta \geq 0$, which must hold for p^*_{HS} to be positive. A similar calculation applies to the case where some connecting passengers are not served.

[6]Note that all passengers are local under the FC network

[7]To investigate planning outcomes other than full service, an analysis similar to that in sections 2 and 3 must be carried out. First observe that, from the planner's point of view the market area of a flight is based only on net trip benefits (gross benefit net of schedule delay and travel-time cost) Therefore. the market area of a flight is found by setting p and P equal to zero in (4) and (17) The resulting expressions are then substituted into the appropriate welfare function for each network type. modified to take into account the possibility of partial service This leads to welfare expressions for the FC and HS cases that have forms similar to (12) and (24) Analysis of these expressions. which parallels that for

Noise Social Cost and Commercial Flight Charge Mechanism -- A case study of Amsterdam Schiphol Airport

Peter Morrell[1] and Hsiao-ying Lu[2]

Abstract

With the continuous growth of the global air transport industry, the environmental issues are undoubtedly becoming increasingly crucial and controversial. The fulfilment of sustainable development, which seeks continued economic growth with limited environmental deterioration, is the goal which many countries are now pursuing

Of the various environmental instruments, environmental charges have been proved to be an effective way to internalise the externalities, while, on the other hand, encouraging airlines to use more environmentally friendly aircraft Amongst the externalities generated from commercial flights, noise nuisance is the most significant and has the greatest impact on the community surrounding the airport.

There are 16 countries and over 60 airports in the world which apply noise charges on commercial flights, some of which have been applying noise charges for over 15 years, for example Manchester Airport in United Kingdom and Amsterdam Airport Schiphol in the Netherlands. However, none of these charges is established by measuring the actual nuisance caused by aircraft noise. There is therefore a need for both an analytical and systematic approach to be taken to derive the real social cost of externalities such as noise and air pollution. Besides, noise charges ideally should be based on the actual social cost, the subsequent impact on the air transport market and the effective way of applying the charges, so that the maximum social welfare objective can be achieved.

From the above, this paper develops mathematical models to calculate the noise social cost in monetary terms and establishes the subsequent noise charge mechanism, using Amsterdam Airport Schiphol as the case study. The hedonic price method is applied to calculate the annual social cost of aircraft noise during the landing and take-off stages of the flight. This is done by estimating the implicit costs of aircraft noise imposed through a decline in property values in the vicinity of the airport. Several noise charge mechanism and scenarios are derived according to the modelling results as well as the environmental objectives of the airport related authorities

Keywords. Externalities, Aircraft Noise, Hedonic Price Method, Noise Charges

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above, yields the following conclusions. Under the FC network, the planner provides service if $c \leq 2\bar{c}_{FC}$ holds, choosing not to provide service otherwise. Comparing (14), the planner is thus more likely to provide FC service than the airline. In addition, the planner provides HS service if $c \leq 2\bar{c}_{HS}$, but provides full service only if $c < 2\tilde{c}$ holds (no service is provided if $c > 2\bar{c}_{HS}$). Thus, comparing (26)–(28), the planner is more likely to provide HS service and more likely to serve all passengers than is the airline. Recalling that the relation between $\bar{c}_{FC}$ and $\tilde{c}$ is ambiguous, as noted above, it follows that for the planner to provide service under the FC network and to provide full service under the HS network, $c < \min\{2\bar{c}_{FC}, 2\tilde{c}\}$ must hold. For the airline to make the same choices, the condition $c < \min\{\bar{c}_{FC}, \tilde{c}\}$ from section 3.4 must also hold. Because satisfaction of latter condition implies that the former is satisfied, the condition $c < \min\{\bar{c}_{FC}, \tilde{c}\}$ suffices. It ensures that both the planner and the airline choose to provide service under the two network types, while providing full service in the HS case.

[8]Total flights equal $3\sqrt{aD/2c}$ and $\sqrt{6}\sqrt{aD/2c}$ under the FC and HS networks respectively

[9]Zero fares are required in the HS case when some passengers are not served. In this situation the last passenger added to a flight should have net trip benefits (gross benefit net of schedule delay and travel-time cost) equal to zero, which requires a zero fare. But in the case where all passengers are served, net trip benefit is nonnegative for passengers with the largest schedule delay, so that the planning solution could be implemented with positive fares (these may not cover airline costs, however).

[10]It can be shown that the same conclusion holds when c takes a value such that service is provided in the FC case and partial service is provided in the HS case.

1. Introduction

With the recognition of environmental issues in global air transport, several international conferences concerning environmental matters for airports and airlines have already been held, especially in recent years[3] [ACI Europe, 1998; Hamburg Airport, 1999]. With the pursuit of sustainable development, which seeks continued economic growth with limited environmental deterioration, more and more airports consider environmental constraints to be amongst the most important factors which determine airport capacity [OECD, 1997; Keur, 1998].

The externalities generated from commercial flights have various impacts on air quality, noise, water quality, fuel consumption & energy, waste and the ecology etc. Noise nuisance is undoubtedly the most significant of these and has the greatest impact on the community surrounding the airport.

The first and most obvious world-wide environmental classification of aircraft is the one described in ICAO's Annex 16 noise standards [ICAO, 1991], where jet aircraft are subdivided into 3 different Chapters according to their noise certification:

- Chapter 1: aircraft with type licence before 1970 (e.g. B707s)
- Chapter 2: aircraft with type licence between 1970 and 1978 (e.g. B747-100/200s, certain B737-200s with Pratt & Whitney JT8D engines)
- Chapter 3: aircraft with type licence after 1978 (e.g. A310, B757, B767, MD83)

An international standard of noise compliance was agreed through ICAO, such that "all Chapter 2 aircraft would be banned from 1st April 2002," and accepted by the airlines world-wide. However, the European Commission has been considering a more stringent regulation against hushkitted Chapter 2 aircraft operating within EU nations, which has recently been the subject of much controversy between USA and EU.

Besides the global standard laid down by ICAO, most airports also have their own specific noise environmental management measures, which can be classified into noise abatement procedures, ground operations restrictions, night flight restrictions, noise surcharges and discounts and noise penalties [Morrell and Lu, 1999]. Each of the measures, generally very specific to particular airports, targets different environmental objectives set by each airport Of the various environmental instruments, environmental charges have been proved to be an effective and economic way to internalise the externalities, while, on the other hand, encouraging airlines to use more environmentally friendly aircraft [OECD, 1994; EEA, 1996]

There are 16 countries and over 60 airports in the world which apply noise charges on commercial flights However, none of these charges is established by measuring the actual nuisance caused by aircraft noise Therefore, there is a need for both an analytical and systematic approach to be taken to derive the real social cost of noise nuisance generated from aircraft movements. Besides, noise charges ideally should be based on the actual social cost, the subsequent impact on the air transport market and the effective way of applying the charges, so that the maximum social welfare

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[3] ACI- Airports Council International, Greenport '99 Thinking green-strategies for balanced airport development in the next century," 21-23 April 1999, Amsterdam Airport Schiphol, the Netherlands

objective can be achieved

From the above, this paper firstly examines the current noise charges which are now in effect at world-wide airports.   After reviewing the methods of measuring externalities, the mathematical models are then subsequently developed in order to calculate the noise social cost in monetary terms, and establish the various practical noise charge mechanisms, using Amsterdam Airport Schiphol as the case study.

2. Current noise charges at world airports

The world-wide airports which currently apply noise related charges or taxes are reviewed and analysed in this section. Furthermore, the noise charges at various airports are also calculated for selected aircraft types and compared in the European currency unit (). For the case study airport, Amsterdam Schiphol Airport, it was important to include both airport and Dutch government noise charges in this review, in the light of the more detailed analysis later (Section 6).

2.1 Noise charges at the world wide airports

Some airports at eleven European and four Asian countries as well as the United States currently apply aircraft noise surcharges and discounts[4]. Table 1 shows how each of them calculates the charge. Most airports apply a percentage surcharge or discount on the MTOW based landing fee, depending on the aircraft acoustic category (the Swiss airports apply a fixed amount surcharge). In the case of German and BAA London airports, the total landing fee varies according to aircraft acoustic noise category, such that it is impossible to separate out the noise element of the charge.

Figures 1 and 2 show the noise surcharge or reduction on some Chapter 3 and B737-200 Chapter 2 aircraft at those airports where this can be shown separately, expressed in terms of Euros () per landing.

The surcharges for the Chapter 3 aircraft revealed some inconsistencies: the MD-83 pays a lower surcharge at Tokyo-Haneda, Sydney and Rome compared with a B757-200, but a higher surcharge (or lower discount) at some airports. The noisier B767-300 pays a comparatively higher surcharge at Tokyo-Haneda, Sydney, Prague and Schiphol airports, as would be expected, but gets a deeper discount at Paris CDG, Brussels and Stockholm This apparent anomaly is because the two aircraft, B767 and B757, are placed in the same charging class at the last three airports, while also applying the discounts as a proportion of the landing fee, which is obviously higher for the heavier aircraft

There was a wide range of surcharges applied for a day-time landing with a Chapter 2 B737-200, ranging from only 17 at Rome to 2,406 at Amsterdam Airport Schiphol. Night surcharges were higher than day surcharges at some airports

Table 2 shows how the noise surcharge revenues are used in six European countries It can be seen that in all cases the airport noise charges were revenue neutral (or they

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[4] Other noise related surcharges at some airports are defined as noise penalties [Morrell and Lu, 1999]

resulted in no net increase in revenues) Thus, increases in charges for noisier aircraft were balanced by reductions in charges for quieter aircraft. Where Chapter 2 aircraft operations are falling sharply, discounts for quieter aircraft need to be reduced to maintain income Of the six, five had noise abatement investment programmes, but these were funded from general revenues. The situation for Amsterdam Schiphol was more complicated, in that both airport and government levy noise surcharges, the revenue from which goes toward the noise insulation scheme (managed by the airport). While the airport scheme is revenue neutral, the government aircraft noise tax is not, but is ring-fenced for airport noise abatement investments.

Table 1 The classification of noise related surcharges

Country	Airport	Percentage surcharge or discount on landing fee based on aircraft acoustic categories			Not possible to separate noise charge from landing fee which varies according to aircraft acoustic categories	
		Surcharge	Discount	Night surcharge	Surcharge	Night surcharge
Australia	Sydney	1				
Belgium	Brussels	✓	✓	✓		
Czech Republic	Prague	2				
France*	All major airports	✓	✓	✓		
Germany	All major airports				✓	✓
Italy	All major airports	✓		✓		
Japan	Some Intl airports	3				
Korea	All Intl Airports	✓				
Luxembourg	Luxembourg	✓		✓		
Netherlands**	Amsterdam-Schiphol	✓	✓	✓		
Norway	Bodø	4		✓		
Sweden	Major airports	✓	✓			
Switzerland	Zurich and Geneva	5				
Taiwan	All airports	6				
United Kingdom	Edinburgh	✓		✓		
	Glasgow	✓		✓		
	London-Heathrow				✓	
	Manchester	✓		-		
USA	Some airports	7				

Source Direct airport contacts and IATA aviation charges manual, March 1999

Note:

1 Fixed surcharge per arriving passenger paid by the passenger on ticket
2 Fixed surcharge per tonne based on aircraft acoustic categories
3 Fixed surcharges per EPNdB in excess of 83 units
4 Fixed surcharge per Chapter 2 aircraft
5 Fixed surcharges based on aircraft acoustic categories
6 Surcharges depending on MTOW and EPNdB exceeding 73
7 Specific charge mechanism for the individual airport
* Besides the noise surcharge based on the landing fee, French airports also have noise tax depending on MTOW and the aircraft acoustic group
** Besides the noise surcharge imposed by Amsterdam Airport Schiphol, the Dutch government also imposes the "Governmental Noise Charges," based mainly on the certificated noise level of each aircraft type, at the majority of Dutch airports
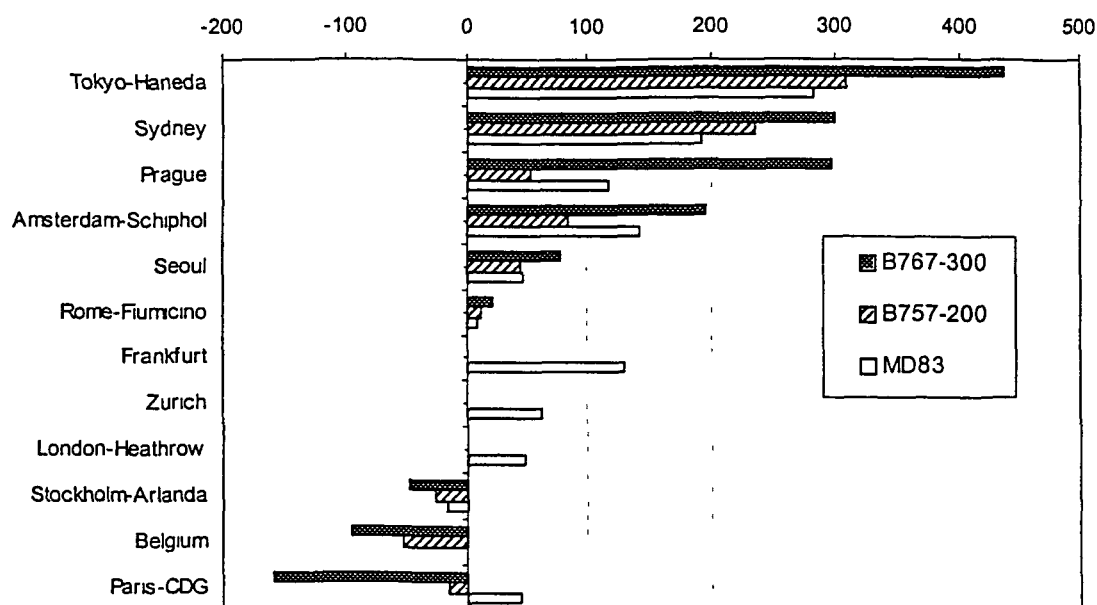
Noise charge/discount (/landing)

Figure 1   Chapter 3 aircraft noise charges comparison

Source: [Morrell and Lu, 1999]

Note:

1   The maximum take-off weights and average seats used in the calculation for each aircraft type are as follows B767-300, 184 6 tons, 269 seats, B757-200, 103 9 tons, 210 seats, MD83, 72.6 tones, 172 seats, B737-200, 54 0 tons, 130 seats

2   The noise surcharge at Sydney Airport is AUS 3 40 per international passenger The calculation is based on the assumption of 0 6 load factor

3   The noise surcharge at Amsterdam Airport Schiphol includes the "Governmental Noise Charge," imposed by the Dutch government at the majority of the Dutch airports

4   The noise surcharge at both Frankfurt and Heathrow Airports are the difference above the landing fees that would have been applicable if the aircraft had been classified as the quietest group

5   The noise surcharge at Paris-CDG includes the "Noise Tax "

Table 2   The application of noise surcharges at selected airports

Airport	No increase in revenue	Noise abatement Investment	Pass on to government
France Paris Charles de Gaulle	✓	✓	✓
Germany Majority of airports	✓	✓	
Italy Rome-Fiumicino	✓		✓
Netherlands Amsterdam-Schiphol	✓	✓	*
Sweden Stockholm-Arlanda	✓	✓	
Switzerland Geneva and Zurich	✓	✓	

Source [Morrell and Lu, 1999]

Note * The money collected from the Governmental Noise Charge" imposed by the Dutch government is entirely used for the soundproofing projects around the airports
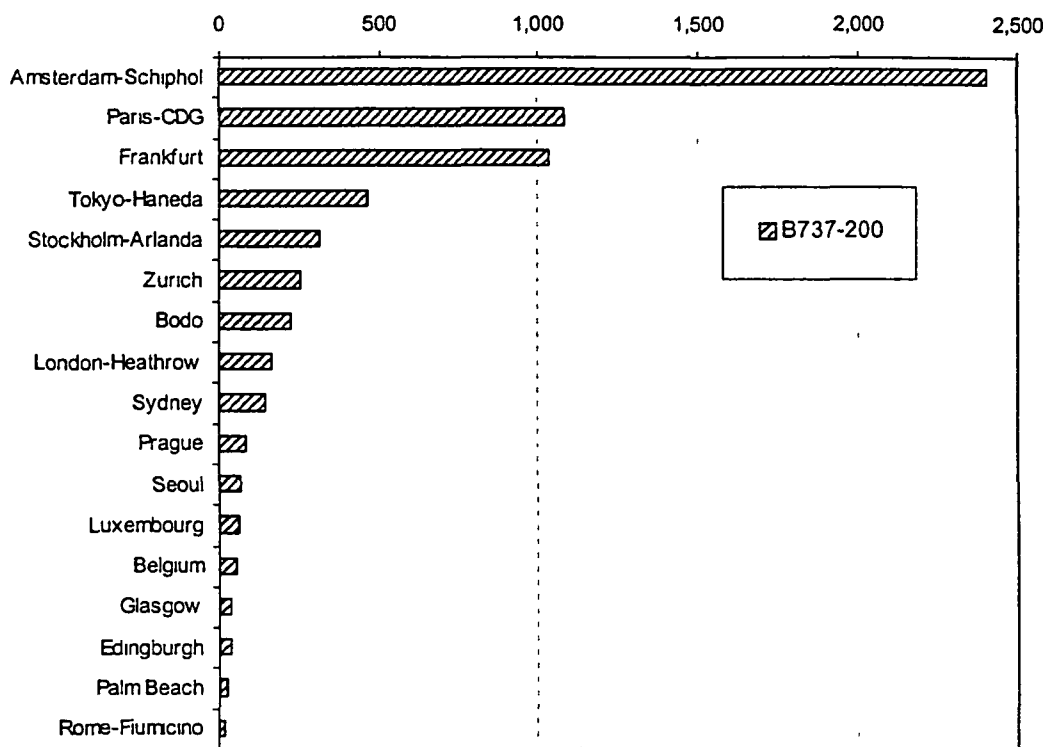
Noise charge (/landing)

Figure 2   Chapter 2 aircraft noise charges comparison

Source [Morrell and Lu, 1999]

2.2 Noise charge mechanism at Amsterdam Airport Schiphol

The aircraft are classified into three categories based on the official certification data of the aircraft (EPNdB), as well as the noise zone calculation model for the airport. Noise Category 3 includes the nosiest Chapter 3 aircraft and all Chapter 2 aircraft, which have to pay a noise charge equal to 7.5% of their basic landing charges. The quietest Chapter 3 aircraft and most turbo-prop aircraft fall into the Noise Category 1, receiving a discount of 2.5% of the basic landing charges. The remainder, in Noise Category 2, receives no noise charges or discounts. Furthermore, the landing fees for flights landing between 23:00 to 06:00 hrs local time are increased by 20% to include a noise surcharge. On the top of these noise charges, Chapter 2 aircraft have to pay an additional noise surcharge, DFl. 2,700 (1,225) for aircraft with MTOW of up to 100 tons and Dfl 4,050 (1,838) for aircraft with MTOW of over 100 tons [Amsterdam Airport Schiphol (a), 1998].

Besides the noise differential landing charges and Chapter 2 aircraft noise surcharges imposed by the Airport, the Dutch government also introduce "Governmental Noise Charges" at most Dutch airports   The noise charge, calculated by the MTOW (for aircraft with a MTOW between 0.39 and 20 tons) and noise certification levels (for aircraft with MTOW larger than 20 tons), is levied on each aircraft landing at a Dutch airport [Dutch Aeronautical Inspection Directorate, 1998]   For example, the noise charges per landing for B757-200s and B767-300s are 95 and 241 respectively.

3. The method of measuring externalities

3.1 The methods of measuring externalities

The methods of measuring externalities in monetary terms have been developed and discussed in several papers. Bateman and Turner [1993] distinguished the methods for monetary valuation of the environment into two groups by the availability of a demand curve. Those commodities which can be valued via a demand curve include the contingent valuation method, the travel cost method and the hedonic pricing method. Those which belong to non-demand curve approaches are the dose-response method, replacement costs and mitigation behaviour. Verhoef [1994], however, classified the methods into the following two categories: short cut approaches, where the actual or potential abatement investment are considered as the external cost, and valuation approaches, which aim at estimating the monetary value of externalities. The dose-response relationship approach, hedonic approaches and the contingent valuation method fall into the latter group.

The study carried out by Pearce and Markandya [1989] for OECD stated that the most well-known techniques for estimating the noise damage costs are hedonic techniques and contingent valuation methods, which both belong to direct valuation techniques. The hedonic price method has been more fully developed in a large number of research papers and surveys; Mayeres et al. [1996] pointed out that the hedonic price method is the most widely used method for the evaluation of noise social costs. Furthermore, it is possible to estimate the social welfare change by utilising the demand curve derived from this approach. Hence, in order to achieve the objectives of this research, the hedonic technique is concluded as the most appropriate method to be applied in the following modelling development.

3.2 Hedonic price method

The most common property value approach, which is used to estimate the implicit prices of the characteristics which differentiate closely related products, is called the hedonic approach [Johansson, 1987]. This is the method based on the household equilibrium marginal willingness to pay, which is used to extract the implicit prices of certain characteristics which determine property values, such as location, attributes of the neighbourhood and community, as well as environmental quality [Nelson, 1980, 1981] It can be expressed as the following function·

$$P = f(S, N, Q) \tag{1}$$

This is a simplified hedonic price function, where P is the vector of housing prices, S denotes a vector of location characteristics, N neighbour and Q environmental characteristics, such as noise, and where $\partial P / \partial Q_i$ is the hedonic price for the noise attribute, which can be considered as the marginal implicit price of noise social costs. However, it is necessary to assume for this approach that each individual has the same utility function in order to obtain the unique price estimation for noise impacts [Pearce, 1979] Subsequently, the Noise Depreciation Index (NDI) or the percentage reduction of house price per dB(A) above background noise, is derived from various studies using regression functions

There have been a number of research studies carried out since the late 1960s quantifying the noise nuisance in monetary terms by using the hedonic price method [Nelson, 1981; Pennington et al., 1990; Uyeno, 1993, Levesque, 1994; Levinson and Gillen, 1998]. Colline and Evans [1994] used an artificial neural network approach to extract the impact of aircraft noise on property values, where the NDI values range from 0.31% to 0.62%, which are similar to those derived from the hedonic price method.

Pearce and Markandya [1989] also summarised the main findings of hedonic price studies on aircraft noise. The results suggest that the NDI would be 0.70% for the unit of NEF[5], and 0.50% for NNI[6], a variation which could be explained by the different ranges of noise level for these two noise descriptors. The average NDI for the aircraft noise surveys summarised by Levinson et al. [1998] is 0.62% with respect to NEF as the noise descriptor.

It is worth noting that Feitelson et al. [1996] used the contingent valuation approach to estimate the willingness of residents to pay for the effects of aircraft noise following airport expansion. This approach provides higher costs than others, where the NDI values are between 1.50% and 2.40%. However, there is still a need for more research to be conducted using this technique, in order to obtain more reliable and accurate results.

4. The noise social cost model

By using the hedonic method discussed above, the annual total noise social cost C_n could be derived from the following formula:

$$C_n = \sum_i I_{NDI} P_v (N_{ai} - N_0) H_i \qquad (2)$$

Where I_{NDI} is the noise depreciation index expressed as a percentage, P_v is the annual average house rent in the vicinity of the airport; and therefore, $I_{NDI} P_v$ is the annual noise social cost per residence per dB(A). The noise level above the ambient level is $(N_{ai} - N_0)$, where N_{ai} is the average noise for the ith section of the noise contour; N_0 is the background noise or the ambient noise. This is finally multiplied by H_i, the number of residences within the ith zone of the noise contour.

The annual house rent P_v could be converted from the average house value in the vicinity of the airport P by the following capital recovery equation, where r is the mortgage interest rate, and n is the average house lifetime [Levinson et al, 1997]:

---

[5] NEF (Noise Exposure Forecast), one of the cumulative noise event measures, reasonably varying between 20-50, was mostly used in the United States prior to the development of the L_{dn} index

[6] NNI (Noise and Number Index), another cumulative event measure normally ranging between 25-45, was used widely in the United Kingdom, but has been largely replaced by L_{eq}

$$P_v = P \left(\frac{r(1+r)^n}{(1+r)^n - 1} \right)$$ (3)

It should be noted that the noise level versus annoyance curve is in a form of non-linear relationship, the higher the level of noise, the increasingly greater annoyance [Finegold et al., 1994; Schultz, 1978]. Therefore, $I_{NDI}P_v$ in the formula (2) ideally should be adjusted by the noise versus annoyance function in order to reflect the real noise nuisance imposed on the residents surrounding the airport. However, the case study conducted by this research, Amsterdam Airport Schiphol, uses the Kosten Unit (KU) as a noise descriptor to express annual levels of aircraft noise, rated according to the aircraft noise level and time of the day. The noise level expressed using KUs already incorporates the non-linear relationship with annoyance discussed above. Hence, the results calculated from the formula (2) can be precisely represented as the noise external cost. This point would not affect the calculation of aggregate social cost, but is important to the later marginal analysis in Section 6.

5. The noise charge mechanism and scenarios

5.1 Noise charge theory and mechanism

Theoretically, the noise charge level is optimal if the rate is determined at such a level where the marginal noise social cost, or welfare gained from the extra reduction of the noise level imposed on the residents, is equal to the marginal abatement cost, which refers to the cost for an extra unit of noise reduction. It can be shown from figure 3 that the optimal environmental quality Q^* is determined where the marginal social cost curve intersects the marginal abatement cost curve at E_q, leading to the optimal noise charge T_m^*, in which the total noise charge revenue R is generated equal to $OT_m^* E_q Q^*$. Alternatively, if the charge is designed to compensate for the total noise nuisance cost imposed on the residents, resulting from the noise level Q^*, then the noise charge is T_a^* where the total revenue is $OT_a^* E_p Q^*$.
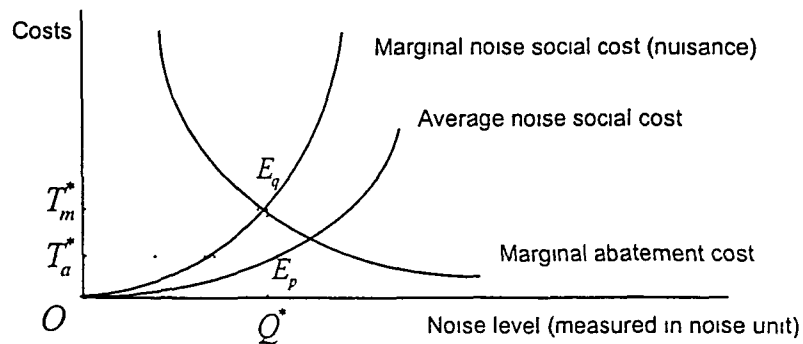

Figure 3   Marginal cost pricing on the pollution market

The factors influencing the marginal abatement cost include the airline's investment in engine modification, low noise abatement procedures regulated by the airport, etc. The insulation investment on the residences would result in the marginal noise social cost curve moving downward.

However, it should be noted that the equilibrium noise level in Figure 3 is based on the assumption that the firm's output decision and its pollution decision are independent. Moreover, the pricing point T_m^* might be applied when the industry could react to the proper pollution level. Hence, pricing at the T_a^* level might be a fair charging scheme for short-term bases. In the long-term analysis, the subsequent impacts on the air transport industry due to the implementation of noise charges on airlines should be incorporated in order to achieve the optimal social welfare.

5.2 Noise charge scenarios

The noise charge for an individual aircraft flight T_t, including the impacts both from take-off and landing stages, could be expressed as the following general form:

$$T_t = \frac{R}{\sum_i L_t} L_t \tag{4}$$

Where R is the total revenue generated from noise charges; L_t is the noise impact index for each aircraft flight. Therefore, the noise charge mechanism could be applied by a two step procedure: firstly, the decision of the total revenue or charges; then the allocation of charges to individual aircraft movements.

As discussed previously, the noise charge mechanism, an economic instrument of internalising externalities, is normally applied by the airport or the government, which depends on the strategic policies of the related authorities There are several methods to determine noise charges for achieving different environmental objectives [Alexandre, 1980; Yeahiya, 1995; EEA, 1996]. According to the implications of noise charges as well as the noise social cost, the total charges R could be decided as follows:

-- Equal to noise abatement investment: depends on the noise abatement investment policy and budget towards the desired noise level or environmental quality; this approach is adopted when the marginal noise social cost curve is unknown.

-- According to marginal noise social cost, depending on the monetary evaluation of the noise nuisance as described in the previous section However, if the noise abatement cost curve is unknown, the desired noise level would need to be agreed by all parties.

The allocation of the total noise charges to the individual aircraft flight should be based on the real impact of noise nuisance on the residents The factors influencing the noise impact include aircraft types, engine types, time of a day, flight paths, landing and take-off procedures etc Summing up the above influential factors, the noise impact index L_t, could be, ideally, derived from equation (2), but with the noise

contour specified for each individual flight or aircraft type.

With regard to the availability of data, the noise contours for certain aircraft types can be easily obtained from the aircraft manufacturers, but the dynamic information for each flight poses certain difficulties. For example, the actual flight path will depend on weather conditions on the day, as well as the ability of the pilot to adhere to the prescribed routing. Hence, the following empirical analysis will be based on the noise certificated level for different aircraft types. Once the detailed data have been obtained, the precise noise charge mechanism could then be derived.

6. The empirical results

6.1 Noise total and marginal social cost

In order to verify the capability of the models developed, Amsterdam Airport Schiphol, one of the airports applying the most stringent noise charges and measures in the world, is taken as the case study for the empirical analysis.

Table 3 The residences within the noise contour at Amsterdam Airport Schiphol

Noise zone in Kosten Unit (KU)	Residences within noise zone	Cumulative residences
> 65	38	38
60 ~ 65	30	68
55 ~ 60	180	248
50 ~ 55	1,325	1,573
45 ~ 50	2,132	3,705
40 ~ 45	3,446	7,151
35 ~ 40	6,908	14,059
30 ~ 35	32,514	46,573
25 ~ 30	56,598	103,171
20 ~ 25	58,065	161,236

Source [Amsterdam Airport Schiphol (b), 1998]
Note: The estimated noise contour for 1999 is used here

Table 4 Aircraft types and movements in the day-time and night-time in 1999

Aircraft type	% of day-time movements	% of night-time movements	Day-time movements	Night-time movements	Total movements
Jetstream 31	5 4	2 1	20,693	284	20,976
F27	15 2	8 1	58,246	1,094	59,340
B737-200QN	0 2	0 2	766	27	793
BAe146-200	23 1	11 9	88,519	1,607	90,126
DC9-30	0 9	0 4	3,449	54	3,503
B737-300	35 2	18 1	134,886	2,444	137,330
B727	0 3	1 1	1,115	149	1,298
A310-203	7 1	17 9	27,207	2,417	29,624
DC10-30	1 8	5 2	6,898	702	7,600
B747-100F/200/300/SP	3 7	15 0	14,178	2,025	16,203
B747-400	3 9	10 9	14,945	1,472	16,416
MD11	3 1	9 1	12,262	1,229	13,491
Total	100 0	100 0	383,200	13,500	396,700

Source [Amsterdam Airport Schiphol (b), 1998]

Table 3 shows the absolute and cumulative number of residences within each noise

contour zone, which is calculated using the forecast fleet mix and number of movements in 1999, as shown in Table 4. The aircraft types are the most commonly used ones at Amsterdam Airport Schiphol, and can be represented as the simplified fleet mix for 1999[7]. The airport in 1999 is allowed to operate 396,700 aircraft movements annually, or 198,350 landings, under the restrictive regulations of Dutch government. The night-time movements will be only 3.52% of the total movements.

With regard to the NDI, the average value concluded from a number of research papers is within 0.60 ~ 0.62 % with NEF as a noise descriptor. The Kosten Unit used in this research ranges from 20 ~ 65 KU, which is 1.5 times the range compared to NEF's 20-50. Therefore, it is theoretically reasonable to adjust the NDI value to 0 40% for the case study. The interest rate in early 1999 was around 4.0% for 10 year Dutch government bonds, to which should be added a risk premium to give a mortgage interest rate of 6.0%, which is used here as the central value. The average house lifetime of 30 years and the average house value of 146,848 in the vicinity of the airport are assumed here [Statistics Netherlands, 1999]. These assumptions will be varied and analysed in the later sensitivity analysis. The 10 KU is used as the ambient noise level, the level at which no residents are defined to suffer serious noise disturbance.

Substituting the above parameters in equations (2) and (3), the total noise social cost is then calculated to be 123.7 million per year, which means the average noise social cost per aircraft movement is 311.8 or 623.6 per landing. However, according to the figures in Table 3, the number of residences within the noise contour zone 20 KU to 10 KU are unknown. The inclusion of these would lead to a slightly higher social cost.

The relationship between the total noise social cost and average noise level can be determined for a potential reduction in overall noise level from 40 KU[8] to 10 KU. Such a noise reduction would be caused either by noise abatement procedures or by the use of quieter aircraft. This is shown graphically in Figure 4, with the marginal social cost curve generated from the derivative of the total social cost equation.

6.2 Potential noise charge scenarios

As discussed in Section 5.2, there are two methods for determining the revenues to be collected from noise charges. These are analysed in this section by using the current airport policy and the previous modelling results.

(1) Equal to the noise abatement investment:

Following the legislation of the Dutch government as well as the airport management policy, there are a total of NLG 550 million (250 million) earmarked for all insulation schemes between early 1998 and 2003 This total expense is being financed by the Dutch Civil Aviation Authority (RLD) and will be recouped entirely by the Dutch Governmental Noise Charges, as mentioned in Section 2 2 [Amsterdam Airport Schiphol, 1997] According to the annual budget spent divided by total aircraft

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[7] Movements of aircraft types using the airport not specified in this list are combined with types of similar noise characteristics

[8] The noise level ranges from the highest noise level, 70 KU to the ambient noise level, 10 KU

landings, the average noise charge per aircraft landing is 157.3, which is very similar to the average figure derived from Dutch Governmental Noise charge rates weighted by movements for each aircraft types.
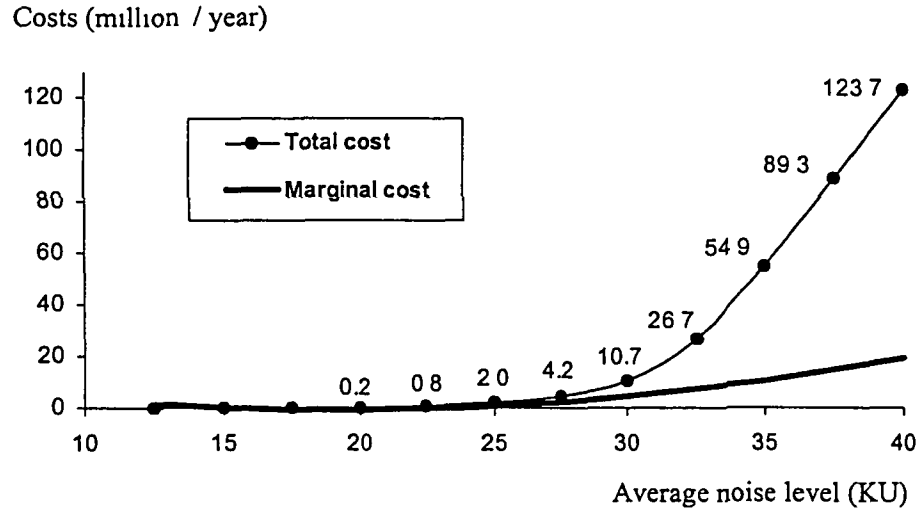
Costs (million / year)

Figure 4   Total and marginal noise social cost

(2) According to the marginal noise social cost:

Table 5 shows the several charge scenarios, ranging from the average noise level of 40 KU to 30 KU, representing the present average noise level to a significant noise reduction of 20 KU for each noise contour zone. For example, a reduction in each noise contour by 10 KU (however this is brought about) to give an average level of 35 KU would give a substantial improvement in environmental quality. The marginal noise social cost per KU incurred in achieving this new position would be 10.7 million per year, in which case the average noise charge per landing, derived from equation (4), would be 1,354.2[9].

Alternatively, at the same average noise level of 35 KU, the total noise social cost, or revenue collected, could amount to 54.9 million where the charge per KU is equal to the average noise social cost[10]. Subsequently, the average noise charge per landing would be 276.7, the right amount for compensating the community surrounding the airport for the noise nuisance they experienced.

Moreover, if the revenues collected from noise charges are invested in the noise insulation scheme, as most of the airports have done, the same noise level might result in a lower noise social cost, as discussed in Section 5.1 Thus, the charge level should

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[9] This charge scheme can be referred to the charge level T_m^* in Figure 3, where the total charge $OT_m^* E_q Q^*$ is generated at the noise level Q^*

[10] This charge scheme can be referred to the charge level T_a^* in Figure 3, where the total charge $OT_a^* E_p Q^*$ is collected for the compensation of the total welfare loss of the residents at the noise level Q^*

ideally be modified subsequently to take into account longer-term effects (the reaction of operators and implementation of noise insulation schemes), until a new equilibrium is reached

Table 5 Noise charge scenarios

Average Noise level KU	Marginal Cost Million / KU-year	Average noise charge (1)* / landing	Total Cost Million / year	Average noise charge (2)** / landing
40 0	19 0	2,875 1	123 7	623.6
37 5	14 6	2,023 5	89 3	450.1
35 0	10 7	1,354 2	54 9	276.7
32 5	7 5	845 7	26 7	134.5
30 0	4 7	476.8	10 7	53 9

Note:
* The total charge = marginal noise cost per KU * (average noise level - 10 KU)
** The total charge = total noise social cost.

Furthermore, in order to incorporate the difference of noise annoyance during the day-time and the night-time, the Kosten rating scale runs from 1 for daytime aircraft movements to 10 for night-time aircraft movements. Furthermore, related research results have shown that the time-of-day corrections for aircraft noise annoyance range from a 3dB to 10dB night-time penalty during the hours from 22:00 to 07:00, intended to account for the intrusiveness of night-time noise and its potential for sleep disturbance [Bullen, 1983; Finegold, 1994]. Using the Kosten penalty, the average daytime and night-time charges per landing can be seen in Table 6, where the average noise charge is applied (see the last column in Table 5).

Table 6 Daytime and night-time noise charges

Average Noise level KU	Total revenue Million / year	Average noise charge (2) / landing	Average daytime charge / landing	Average night-time charge / landing
40 0	123 7	623 6	473 5	4,735.4
37 5	89 3	450 1	341 8	3,418 3
35 0	54 9	276 7	210 1	2,101.1
32 5	26 7	134.5	102 1	1,021.1
30 0	10 7	53.9	41 0	409 5

6.3 Sensitivity analysis

Several important parameters in equations (2) and (3), which might influence the modelling results, are further analysed in this section in terms of the average social cost per aircraft landing. The parameters for the sensitivity analysis performed here include the noise depreciation index, mortgage interest rate and average house lifetime

The results are shown as in Figure 5 With the change of the I_{NDI} value from 0.35% to 0 55%, which is the reasonable range concluded from several survey results, the average noise social cost per aircraft landing ranges from 545.6 to 857 4 Varying the

mortgage interest rate r from 2.0% to 10.0%, the average noise social cost per aircraft landing ranges from 383.2 to 910.5. Furthermore, with the average house lifetime n ranging from 20 years to 50 years, the average noise social cost per aircraft landing varies inversely from 748.3 to 544.6.

Average noise social cost (/landing)
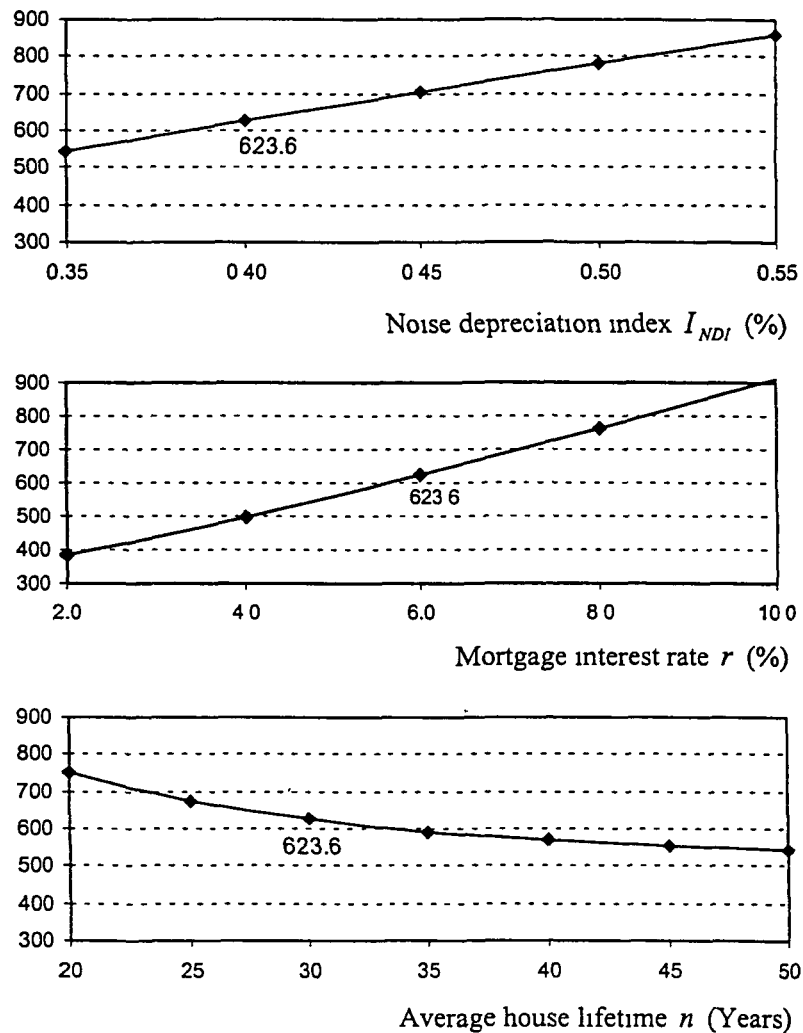
Figure 5   The results of sensitivity analysis on aircraft noise social cost

From the sensitivity analysis above, it can be concluded that the noise depreciation index as well as the mortgage interest rate are more sensitive than the house lifetime with respect to the monetary value of the aircraft noise social cost.

7. Conclusions and recommendations

The results of this paper can be viewed in two parts. Firstly, the current noise related charge and tax mechanisms at the world airports are classified and analysed,

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26 Lufthansa, "*Environmental Report,*" 1997/98, Frankfurt, June 1998.

27 Morrell, P. and Lu, H "*Current Environmental Management Measures in Air Transport,*" Aerogram, Vol 9, No 3, May 1999

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29 Nelson. J P, "*Measuring Benefits of Environmental Improvements Aircraft Noise and*

following the comparison of the noise charge level for different aircraft types. The research results have shown that, besides the internationally agreed environmental restrictions through ICAO, there have been a growing number of world-wide airports introducing specific environmental charges. Amongst these, European airports tend to have stricter environmental measures then others, except Tokyo-Haneda and Sydney airports, which apply the highest noise charges. Given the various noise charge mechanisms at world-wide airports, ECAC's ANCAT committee is developing a common approach to noise charges, which could apply the same formula at different airports, but each airport could impose specific unit charges and noise thresholds [ANCAT, 1998].

Secondly, the hedonic price method is applied to estimate the social cost generated from the aircraft noise nuisance in the vicinity of the airport. The noise charge mechanisms based on economic theories for achieving the optimal social welfare or equality are briefly discussed, which then could be allocated to each individual flight depending on the real noise impact.

The numerical results from the case study of Amsterdam Airport Schiphol have shown that the average noise social cost per landing is 623.6, which is slightly lower than the aggregate value from the previous related study [INFRAS and IWW, 1995]. Considering the sensitivity analysis for several parameters, the average noise social cost per landing could vary reasonably between 400.0 and 900.0. Those values are considerably higher than the average Dutch governmental noise charges, around 157.3 per landing. But insulation schemes cannot fully compensate residents for total noise nuisance experienced. Nevertheless, several noise charge scenarios as well as time differential charges are proposed, which again need further research. This needs to consider the cost benefit analysis of the insulation investment and, most importantly, the implication of noise charges on airline operations and costs.

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Economic Impacts and Land-Use Change Around Major Airports: Some Examples from Sydney Kingsford Smith Airport Based on an Eighty-Year Analysis

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> "Trade not only breeds intercourse and exchange of merchandise. .but also engenders love and friendship between all men" [letter from Queen Elizabeth I to Ala-uddin Shah, Sultan of Archin, 1601 (quoted by Milton, 1999, p 88)]

1. Introduction

In attempting to secure harbours in the Spice Islands (now Indonesia) four hundred years ago the letter from Queen Elizabeth I of England recognises that transport and intermodal facilities have effects beyond that of trade alone In addition to the market forces of buying and selling spices, Europeans had profound and lasting political and social impacts on the indigenous communities surrounding these ports the Portuguese and Dutch built fortifications, there were massacres and retributions; competition was rife amongst various European powers to discover faster shipping routes to the East Indies, and, ultimately, colonial administrations were imposed Of course, the indirect impacts of military and civilian aviation would reflect a differing history but, nevertheless, an equally profound one in the Twentieth Century

The globalisation of the international economy in the late Twentieth Century has been underpinned by technological development in the aviation sector. Out research entails tracing the international treaties and national policies that have given rise to the growth in international networks and service frequency (with particular reference to the Asia-Pacific region) and demonstrating how traffic growth has required a parallel set of policies for airport development and expansion (Jatmika, 1999) More specifically, we have developed a conceptual framework for studying both the positive, economic impacts of airports and also the negative, environmental impacts of traffic growth with the broad aim of devising an appropriate airport/community environmental management system. The research reported in the paper is confined in scope to considerations about the economic impacts of airports and how these impacts manifest themselves on the ground in localities surrounding airports

Here, we discuss the role of transport infrastructure in economic development (section 2) both from a general perspective of the theoretical stages of air traffic networks that draws, in particular, on the work of Goodovitch (1996). The next, complementary section (section 3) reviews the somewhat limited literature on the role of airports in regional economic development Whether local economic development drives airport developmental proposals or whether airport development induces local economic growth remains as unclear today as when de Neufville (1976) raised such uncertainties Clearly, in the environmental impact assessments required by government of today for any major airport proposal there are assumed indirect economic benefits The methods of estimation, such as economic base models, econometric models and input-output models, are reviewed in section 4 Multiplier values are at the core of predicting economic flow-on effects The values of such multipliers for a range of transport infrastructure (including airports) in section 4 provide useful comparative data on the orders of magnitudes anticipated

The basic argument in this paper, and an area where we feel an original contribution is being made, is that the practice of assessing the indirect economic impacts of airports fails to consider explicitly its spatial and temporal dimensions Where does such economic activity occur ? - diffuse through the regional economy ? concentrated in locations close to the airport ? or some combinations whose

approximate proportions have yet to be differentiated ? In attempting to answer such questions in section 5, we have selected Sydney Kingsford Smith International Airport as a case study and have drawn upon secondary sources (for example, Gall, 1986) and primary fieldwork data collected by researchers at the University of New South Wales (for example, Symons, 1971) to provide an overview of land use changes in an eighty-year period from when the aerodrome was established at Mascot in 1919 Importantly, we are able to trace detailed land use and industry change in a small neighbourhood close to the airport over thirty-year period based on repeated field surveys. In approach, this is similar to the work by McCalla et al. (1998) on land use change around selected Canadian ports and airports, but at a more detailed scale.

The significance of our research is that we are plugging gaps in the area of airport land use impacts. Unlike railway stations where localised land use impacts have been extensively studied (for example, Cervero and Landis, 1997; Obermauer, 1998) Airports, as intermodal interchanges, have received relatively little attention in terms of their indirect impacts on the economy. An understanding of such spatial and temporal impacts is an essential prerequisite before embarking on an environmental management system that extends beyond that currently being undertaken by airport managers when grappling with the complex issues of the economic, social and environmental impacts of airport development.

2. The Role of Transportation Infrastructure in Economic Development

Human activities (social, economic, cultural and political) require the existence of transport services (Hoyle and Smith, 1996). Markets have spatial dimensions, because every component of the economy needs the presence of adequate transport infrastructure to provide "door to door" or "floor to floor" access. The market growth is cumulative. As markets expand the demand for other products may also increase, helping to raise the region's income, which in turn, stimulates more production of goods for the former markets. In theory (Kindleberger, 1958) the process continues cumulatively and repetitively until market equilibrium is achieved The history of transport is about technological advances, the deployment of new modes of transport and increasing speeds to provide superior access Human porterage and pack animals dictated that the spatial extent of markets were limited and transport costs is high (Clark, 1982) Globalisation of the economy is now facilitated by supersonic and sub-sonic jet aircraft

The economic history of transport - for example, canals (Goodrich, 1961), railways and roads in Britain (Barker and Savage, 1974) of the impact of railways in the USA (Fishlow, 1965) - is about reducing the costs of transport In locational analysis, the money costs of moving over space have a special place (Richardson, 1972, p 42) For instance, Isard (1956) outlines a simple model where the search for the optimum location involves the minimisation of transport costs, whilst recognising the importance of non-transport (for example, labour) costs Therefore, industrial locations are often near railway or motorways (Tolley and Turton, 1995, p 72) Location theory recognised the importance of junctions on transport networks or of intermodal interchanges (for example, railway terminals) but the general literature on transport and economic development has not adequately addressed the specific case of airline networks and airports

Moavenzadeh and Geltner (1984, p 89) argue that the development of social, economic and political movements requires a certain stage of transport development Transport is fundamental in connecting economic activity centres Socially, transport infrastructures support travel. Economic activities, which can be induced by social interactions, may further develop Politically, national unity, security and stability can be maintained (Cooley, 1898) Political stability will help to create conditions which are conducive to the reaching of equitable economic development. To achieve this, transport infrastructures provide two main supports for economic activities: accessibility and mobility

Firstly, transport facilities provide accessibility for economic activities. They connect different locations of resources, producers, markets and consumers by eliminating the "tyranny of distance". The connection is depicted in Figure 1. Secondly, transport infrastructure facilitates industrial process activities Natural resources and intermediate products are hauled to the production centres from various locations Final products are consigned to domestic and overseas consumers Both domestic markets and international markets can be expanded with better transport. This will enable economy of scale in the production process Eventually, production costs may decrease and product competitiveness may be improved.
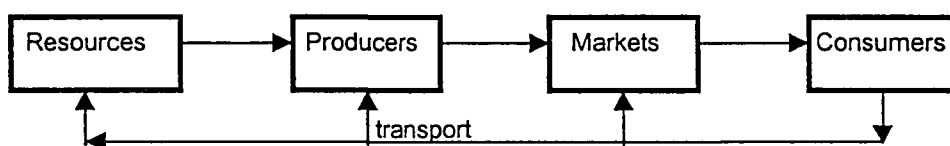
Figure 1. Economic Activities Interrelation

Source Adapted from Warpani (1990, p 4)

Connecting different centres of economic activities may create spatial interchange between regions (Robinson and Bamford, 1978) The interchange may occur between centres of economic activities (growth poles) or between the growth poles and their surrounding areas. There are three factors affecting spatial interchange: the availability of commodities, outer region demand for the commodities and the movement of the commodities from the production centres to the consumers. These activities can create place-utility values for the commodities This means that the value of the products in the new locations is higher than in their original places. Moreover, commodity flow will further spread the markets within and outside the region The widening of the markets through transport improvement can help to promote economic growth (Owen, 1987)

Transport infrastructure can provide greater mobility for economic activities In modern economies, mobility becomes increasingly important For example, companies tend to establish their offices either near major airports or in places with easy airport access to facilitate their business travel High-value-added industries are also inclined to establish their factories near the airports. The globalisation of economies enables companies to locate their production factories in different countries and in different regional areas Consequently, just-in-time delivery is very important to support the punctuality of production process Japan, for instance, established her semi-conductor plants in the Asian countries because of cheaper labour costs (Shibusawa et al , 1992) Then, the intermediate products must be delivered to their final assemblies in Japan Those production processes rely heavily upon the punctuality of delivery of the intermediate goods The delay of a good's consignment may disrupt the

entire production processes Furthermore, it may cause serious loss of profit to the firms and eventually, they may lose their ability to compete

Perspectives on the role of transport infrastructure in economic development have changed overtime There are three kinds of role that transport can play in economic growth positive, neutral or negative Prior to the 1960s many believed that transport facility could promote economic growth (Gauthier, 1968) This viewpoint has changed since the late 1960s when Storey (1969) argued that additional transport infrastructure might also have negative, or, at best, have neutral effects on economic growth Hoyle and Smith (1996) further contend that the role of transport infrastructure provision in economic development has been no more than permissive, or conditional. Without attempting to review these three propositions here (see Jatmika, 1999, chapter 2), we point out that the literature on the role of transport infrastructure in economic development is somewhat limited (Hoyle, 1973, Robinson and Bamford, 1974, Eliot Hurst, 1978; White and Senior, 1983; Owen, 1987; and Simon, 1996)

Eliot Hurst (1974) claimed that the role of transport-infrastructure in economic development is neutral The infrastructure develops in line with the economic growth This argument, however, cannot be generalised In some cases, excessive infrastructure provision has a negative impact on economic growth. For instance, in the countries having adequate transport provision, that argument may be true. In these countries an efficient provision of transport facilities is more crucial However, in the areas having undeveloped infrastructure, lack of that provision may militate against economic development In this case, the presence of an adequate infrastructure is very important in stimulating the output growth. The supposition that infrastructure initiates economic development seems to be true Transport facilities provision is therefore contingent upon the level or phase of the economic development.

It is important to discuss a developmental model for roads because of its influence on a model for air traffic networks developed by Goodovitch (1996) Taaffe et al (1963) used historical experiences of the development of a West Africa country's transport network in which comprises seaports and roads networks, as the basic approach. This model attempts to incorporate the spatial aspect in economic development There are six stages in the development of transportation in developing countries. Stage one is denoted by small isolated ports in coastal areas Stage two is marked by the linear penetration of roads into the peripheries from the seaports These roads are not interconnected New activity centres are established alongside these roads in stage three Further inland road expansions occur Stage four is characterised by the initial road-network construction linking major centres of activities In stage five, networking advancement takes place following economic development of each centre or node. Some centres grow more rapidly than the others A complex and sophisticated network is constructed. Road hierarchy begins to appear in stage six It describes the high level of social and economic interactions between the developed centres The level of social interaction and economic development is indicated by the size of traffic flows between centres The greater economic development and social interactions the larger the size of a node and the larger the traffic flows between the developed nodes Furthermore, new road constructions begin to decline Existing road improvements, particularly the main roads between developed nodes, are more essential at this stage Eventually accessibility and mobility in the region become higher In practice, this concept seems to be applied for almost all developing countries, especially in the early development of their transportation network

The development stages of air traffic network are somewhat different from Taaffe's model. Goodovitch (1996) postulates a general model explaining the development phase of air traffic network, has six phases (Figure 2 as with Taaffe's model) In phase one, there are few scattered and isolated airfields These airports are still disorganised and have irregular services In phase two, scheduled air service between airports begins to operate but are still very limited Inter-city services develop gradually in phase three. At this phase, every city is fully interconnected by the air service. However, this interconnection is considered as inefficient. Phase four is denoted by more efficient air route connection between cities. It contains one primary airport linking other peripheral airports and each adjacent
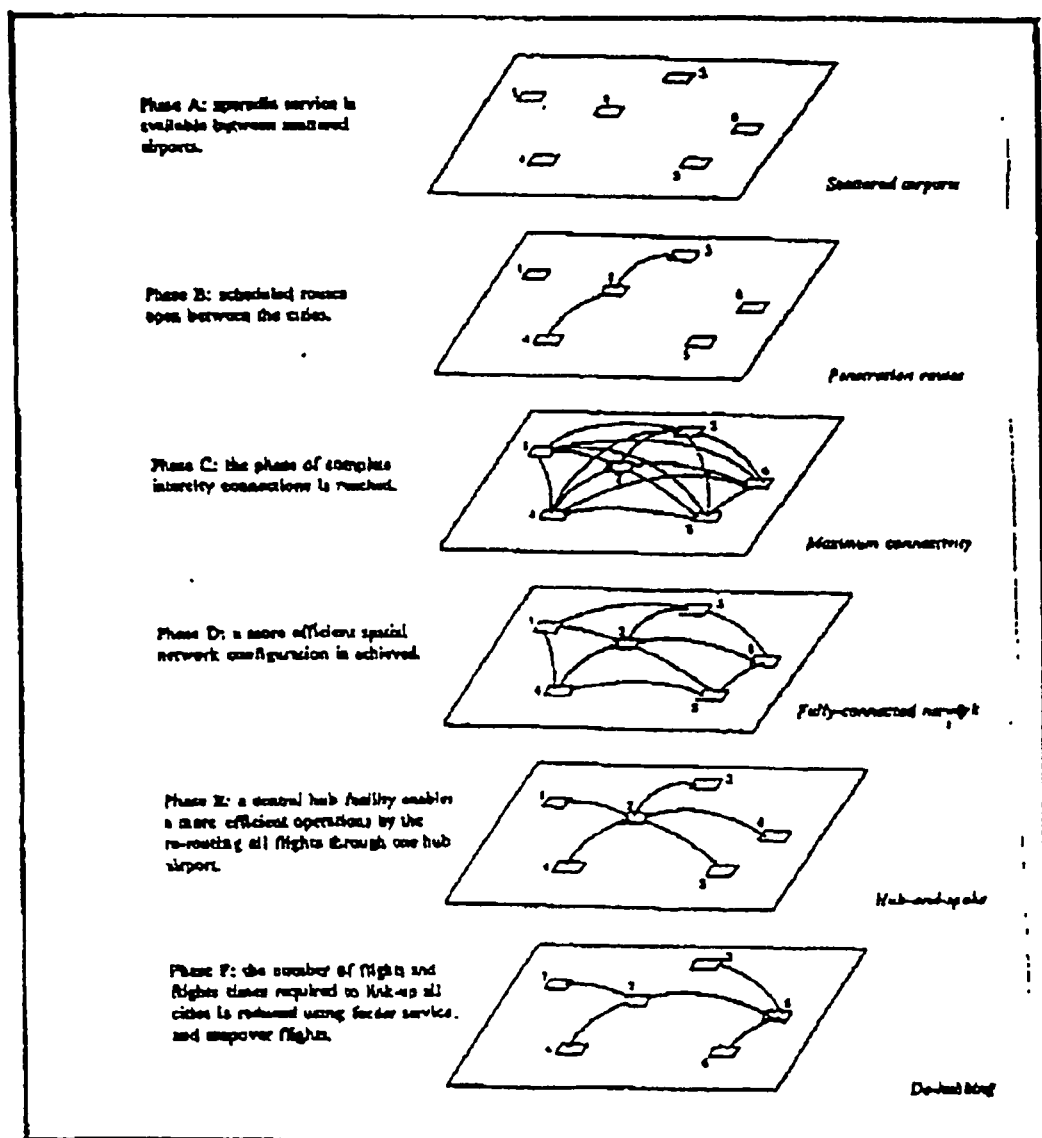

Figure 2. A Model for Air Transport Development

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peripheral airport is interconnected The concept of hub and spoke is introduced in phase five All flights between peripheral airports are channeled through the hub airports This system is better than the previous network in the sense that the number of air routes can be reduced significantly. Phase six is marked by de-hubbing process in air traffic network. A secondary hub is introduced in the air traffic network The latter system can operate less aircraft than that of a hub-and-spoke system. Moreover, the de-hubbing system is able to decrease total block hours of aircraft operations. This model, however, needs to be used carefully. It does not apply to international air traffic network development owing to the existence of bilateral air agreement between any two countries. International agreement usually hinders the formation of the proposed air traffic pattern. Therefore, Goodovitch's model is more likely to occur in the development of domestic air traffic network in which there is no trans-boundary permissions are required to expand the network between regions.

Hoyle (1973) further argues that there are two phases of modern transportation network evolution: *original transportation facilities establishment and advance transportation development.* The first phase occurs in early economic and regional development of a nation At this time, there is no infrastructure constructed. The provision of main railroads, seaports, and roads takes place at this stage Thus, at this stage the infrastructure acts as a trigger for the economic growth The second phase takes place in the presence of the previous transport infrastructure and this condition applies to the developed countries as well. At this level, the role of the transportation facilities is unclear in economic development. An efficient utilisation of the transport-infrastructure is more important to achieve higher output growth. To gain optimal economic development, integrated development of the transport sector with other sectors should be conducted. Beyond the optimal capacity, transport infrastructure will be useless. Transport infrastructure development therefore will be dependent upon the economic development level of the country

Basically, Taaffe's concept is similar to that of Hoyle Stages one and two of the Taaffe concept are the same as the initial transport-provision phase. Transport facilities are essential for economic development, to haul resources to the production centres or the consumers via the seaports. Stages three to six are similar to the transport-elaboration phase Economic development may proceed with or without the improvement of transportation It means that there are other factors affecting economic growth, such as health and education The budget allocation for the provision of transportation facilities must compete with other sectors to achieve significant economic development In other words, efficiency has become the key issue for providing transportation facilities In the last stage of network development, an efficient management of transport facilities provision plays a more important role in the regional growth

The role of airport in the first two phases of the Goodovitch's model in sparking economic development is unclear This only describes the initial stage of transportation-provision. Air transport initially served military and postal service purposes During this phase, the role of seaports and land transport was more prominent The role of airport in economic development commenced at a later stage of economic development As a nation becomes more prosperous, and time-value becomes more precious for business activities and cargo consignments, the utilisation of air transport, especially in the

developed countries, increases tremendously This occurred in the early 1960s in which at the same time the world's GDP grew steadily (World Bank, 1994) and tourism activities began to increase significantly (Graham, 1995, p.4) Air transport services became affordable for passenger travel and for cargo shipment. Wide-bodied and long-range jet aircrafts were introduced and strengthened the importance of air transport and airports in business activities. Goodovitch emphasises the importance of network development efficiency which was initiated after the US airline deregulation in 1978 Deregulation strongly promoted free competition mechanism within air transport industries and the demand for air transport from both air passengers and airport-related industries also increased significantly Goodovitch's model clearly shows an historical evolution of air traffic network patterns to achieve the most efficient provision of both airport and air traffic services Within these phases an efficient provision of airport facilities is able to encourage economic growth in its surrounding areas in the way that airport can expedite the economic activities of airport-based industries In summarising the stages of transport infrastructure provision and its role in economic development it is instructive to compare Goodovitch's model with two widely accepted models of transport and economic development - those proposed by Hoyle (1973) and Taaffe et al. (1963) as shown in Table 1.

Table 1 Stages of Transport Infrastructure (TI) Development and Its Role in Economic Growth

| Stages of TI Development			Roles In Economic Growth	
Hoyle's Model	Taaffe's Model *)	Goodovitch's Model **)	Taaffe's Model	Goodovitch's Model
Original TI Provision	Scattered ports	Scattered airports	Essential	unclear
	Penetration lines and port concentration	Penetration of air routes	Essential	unclear
Advance TI Development	Feeders development	Maximum connectivity	Needs efficiency considerations	Needs efficiency considerations
	Commencement of interconnection	Fully Connected network	Needs efficiency considerations	Needs efficiency considerations
	Complete interconnection	Hub and spoke network	Needs efficiency considerations	Needs efficiency considerations
	Emergence of network hierarchy	De-hubbing of network	Needs efficiency considerations	Needs efficiency considerations

*) Adapted from the Taaffe, Morrill and Gould Model (1963)
**) Adapted from the Goodovitch Model (1996)

The implications of the models discussed above are that they emphasise the spatio-temporal dimension of transport infrastructure development and economic growth The exact extent of economic impacts will depend on the stage of development of the transport infrastructure This clearly has implications when analysing the indirect impacts of airport investment in countries which have differing levels of economic development and growth Forkenbrock (1990) argues that there are two different types of transportation investments new facilities, especially in undeveloped areas, and marginal improvements to existing facilities The main issue for many situations is the extent to which the marginal enhancement of transport facilities can be economically justified in the sense that increases in benefits will be greater than the costs incurred (Figure 3)

This needs prudent investment measures that takes into account efficiency considerations in the provision process Economic impact assessment and analysis has thus become an important in project appraisal in the general environmental impact assessment process As noted in Figure 3, there are four

additional aspects in order for any transport infrastructure, including an airport, to achieve a positive economic development impact. These factors include productive capacity, entrepreneurial skill, financial institution and good trade condition (Hoyle and Knowles, 1996) The level of economic growth, which is triggered by additional provision of transport facilities, is heavily dependent on human initiative Economically, the facilities provision, whether by private or public investments, has the potential to create economic opportunities such as extracting potential natural resources and attracting new business activities into a region. The presence of human entrepreneurship is crucial at this stage to respond these new opportunities by selecting productive activities and conducting profitable businesses through a good anticipation of growing demand from the entire region or nation.
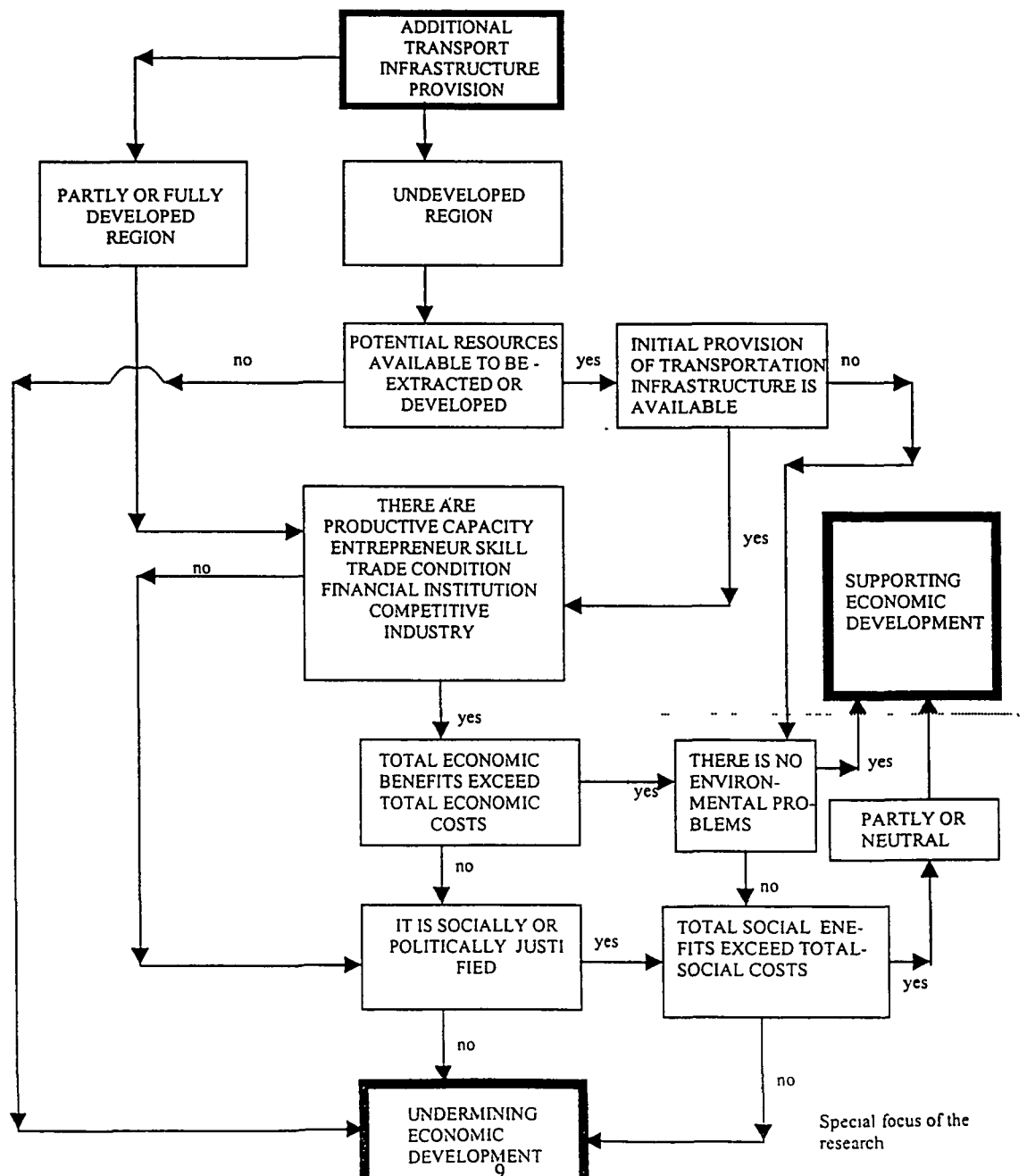
Figure 3. Possible Impacts of Additional Provision of Transport Infratsructure

For commencing and conducting economic activities, they need the availability of funds or capital and the presence of financial institution This institution, such as banking institution, lies at the heart of economic activities through its ability to expedite business transactions Economic output produced by these economic activities needs to be exported to other regions to gain revenue In this case, export is regarded as the main source of regional revenue. Good trade condition will enable the exporting region to maximise its revenue, and profits, from trading activities with other regions The improvement of profitability might increase income and create more jobs Eventually, this will help the provision of transportation infrastructure to have a significant contribution to regional economic development. In their arguments, however, Hoyle and Knowles (1996) provide only little explanation on the importance of economic efficiency considerations in the provision of additional transport infrastructure

Forkenbrock (1990) provides greater insight to the issue of economic efficiency in providing transport infrastructure in order to achieve significant regional economic growth He employs the concept of benefit-cost in his explanations His argument emphasises the importance of foreign and private investors to stimulate efficient economic activities in a region. In this sense, industry-sector has been the driving force for economic growth There are six additional conditions in order the provision of transport infrastructure to achieve positive impact of economic growth

1   Duplicative investment in transport facilities having an identical function as the other one should be avoided. This will create inefficiency since an additional incremental benefit of the new provision will fail to occur It will only waste a large amount of capital costs having been better allocated to the alternative uses

2. The entire benefits spread to the whole community in the region surpassing the total social overhead costs incurred by the additional facilities In such cases, there is no subsidy is required Lower subsidy means lower taxes which might improve the economic wellbeing of the people By doing so, economic efficiency can be achieved

3   The incoming investors from other regions should be encouraged while intra regional shift of the existing investors should be avoided. The former may induce economic growth due to additional influx of funds and the latter tend to reduce total benefits owing to relocation costs it might incur

4   The provision of facilities circumvents the equity objective instead of economic efficiency Unless total benefits exceeds total costs the equity judgement may undermine economic growth

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5   The development of transport infrastructure in the untapped region having potential resource endowment should be carried out carefully on the basis of efficiency considerations

6. Facility provision for footloose industry is inefficient unless its total capital expenditure exceeds total costs of transport infrastructure.

There are many variables determining economic development such as resources, lifestyle, preferences, investment, income, employment, government expenditure, export, import, technological development and community leadership. In the benefit-cost analysis, only some of them can be quantified. Some variables, including lifestyle, preferences and community leadership, are very difficult to quantify. Consequently, the results of the benefit-cost analysis become limited. In some cases, the facilities development can be justified for social or political reasons. The issues of equity and security in a nation have been the good examples. In this matter, as long as these provisions can bring more social benefits than social cost, it is still regarded to be efficient. Nevertheless, there are still possibilities that this justification may partly contribute or even neutral to economic growth of a region. Otherwise, additional or new investments in transport facilities will undermine economic development.

In the sense that efficient condition has been achieved, environmental aspects, including social impact assessment, needs to be further evaluated (Nero and Black, 1998). Many articles discussing transport and economic development do not provide the detailed negative environmental impacts of transport facilities provision on economic development. Environmental negative impacts, such as noise, pollution and vibration, create external costs to surrounding economy. In this case, surrounding people bear the costs without given any compensation from transport users. As a consequence, the quality of life of surrounding people will decline and this can be stated in monetary value or to be internalised. The internalisation of the external costs of transport will reduce the total economic output. If total benefits still transcend total costs including external costs, positive economic growth can still be expected. Otherwise, economic development will be discouraged. This conceptual framework applies for all forms of transport facility provision. However, the role of specific transport infrastructure, like an airport, in regional economic development needs further discussion, and this is attempted in the next section

3. The Role of Airport in Regional Economic Development

Some governments regard that the development of airport infrastructure is an important policy means to promote contemporary economic development. In fact, regional characteristic and special economic condition determine the type of economic impacts of airport on local economy (Cooper, 1990). Most studies agree that airport-related economic activities extend beyond the airport boundary. Whether airport induces local economic development or local economic development drives airport still remains uncertain (de Neufville, 1976). The former framework analysing the possible role of transport infrastructure in encouraging economic development will still be adopted in the case of describing the airport's role in regional economic development. In this specific case, however, some other considerations, such as economic development stage of a country, type of airport-dependent industry and airport size, need to be further discussed

The importance of air transport in economic activity began to emerge in the early 1960s. Previously, air transport had mainly operated with a heavy subsidy from the government. Preserving

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aerospace industries for defense and employment purposes has become an official justification for protecting air transport industry operations. The economic viability of the air transport industry became increasingly stronger commensurate with the aircraft technology and world economic development, particularly in the developed countries. The introduction of long-range and wide-bodied jet aircraft has increased the role of air transport in expediting business activities, including air cargo shipments. The demand for air transport from international tourism has also improved tremendously since the 1960s. Due to this economic maturity, air transport is considered to become a self-sufficient industry. Accordingly, excessive subsidies from government are being revoked. The efficacy of airport infrastructure to induce economic development is contingent upon the stage of economic development of a country. Air transport is a high-cost industry. It requires a great deal of capital and operation costs for both facilities and equipment. In developing countries, the operations of airports tend to have negative economic impacts (Graham, 1995, Cervero, 1992; Leinbach, 1989) and they need considerable amount of governmental subsidy to cover these costs. In some cases, airports operate with heavy losses. In many airports, air traffic demand is relatively low so that total aviation revenue is inadequate to cover total airport operational costs. This creates detrimental impacts on overall economic development and the subsidies would have been better allocated to other alternative uses.

There is one exception whereby the airport has an enabling role in economic growth. In archipelago states, like Indonesia, or large nations having many mountainous barriers, such as Papua New Guinea and China, airport provision for conquering distance to the remote areas can be considered as having influence in shaping the spatial and political integration of a nation (Graham, 1995, p.200). Political stability becomes a necessary condition to create a situation which is conducive for enabling economic growth in developing nations. However, this condition is inadequate to gain the expected economic growth. For the positive effect of airport to occur, the subsidy for its operation needs to be removed gradually. any form of subsidy may undermine economic efficiency because the subsidy might incur higher taxes for maintaining the low cost transportation operations. As a result, disposable incomes and social welfare of a country will decline. In this sense, investment inefficiency in airport provision will occur when social costs are greater than social benefits.

Graham (1995) argues that the role of major airport expansion in developed countries generally has positive effects on economic development. Some studies support his arguments. Tourism has been the primary users of air transport service in these countries. In the developed nations, with high levels of economic welfare and income, leisure has become an important basic need for people. In this case, tourism, especially international tourism, has been the driving force inducing tremendous demand for air transport (Taneja, 1988, p 32). This will need good provision of airport to anticipate this growing demand. The expenditure of tourists might help to encourage local economic activities which eventually may help to induce economic development in the region.

Airport-dependent industry is also considered as having the potential to enhance regional economic growth. This argument, however, has some exceptions. Small airport having complementary industry with that of the adjoining major airport's industry might support a significant economic growth to local economy. In the case that the industry has a competing product with the industry in the nearby major airport, the small airport may experience a backwash effect from the adjacent major airport (de

Neufville 1976) This means that a major airport has more economic advantages, such as localisation and agglomeration economies, than smaller airports in the periphery in improving regional economic development At major airports, further cost benefit analysis should be carried out to assess the possible economic impacts that airport can induce. If total economic benefits are more than total costs and the industries are classified as airport-dependent industries, a positive economic impact might be expected In the case that the industries are not categorised as airport-related industries, the economic impacts remain unclear although its total benefits exceed its total costs These benefits might still occur in the absence of an airport. Figure 4 depicts the whole discussion.
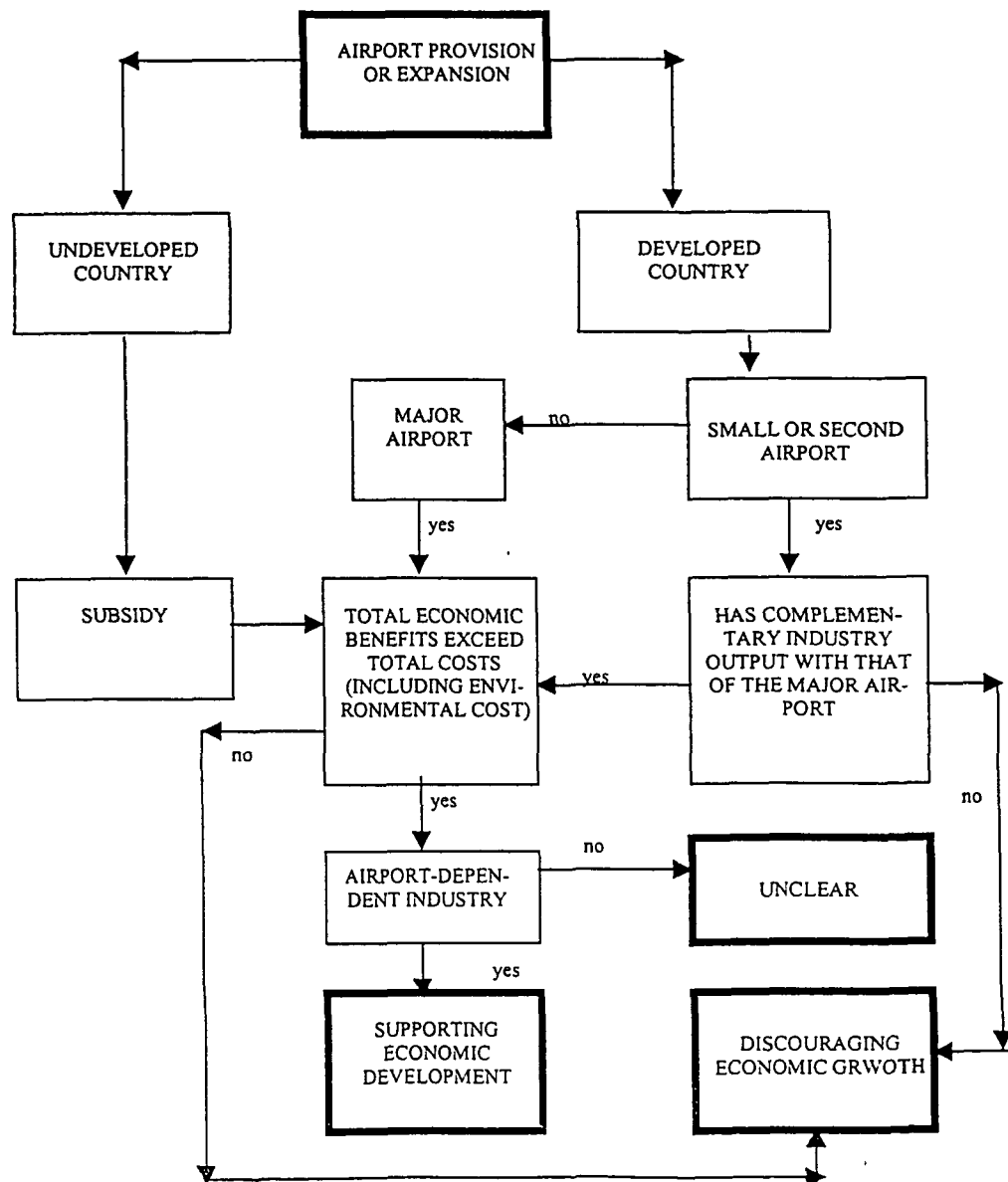
Figure 4. Possible Role of Airport in Economic Development

Cooper (1990) further argues the correlation between major airport and its airport-based industries is still speculative. Only certain industries are suitable for stimulating economic growth. These industries comprise computers and their appliances, communications equipment, semiconductors, aerospace and electronic components. Of these, the semiconductors industries are the heavy users of, and mostly dependent on, airport services The correlation between these industries and airport activities has positive values: access to air transport is the main determinant for business location (Leeper, 1988) In the era of globalisation, whereby the production process can be conducted in different continents, the role of an airport in expediting the just-in-time delivery becomes increasingly important. These markets require the punctuality of the distribution of final products to the their outlets worldwide This necessitates the improvement of high technology industries' efficiency to overcome the severe competition in the world market. The industries have spillover effects on, and need supports from, the local economy. This will help to invigorate the economy in the airport's vicinity and to stimulate economic activities in the surrounding areas.

4. The Methods of Economic Impacts Estimation of Airport Operations on Local Economy

The literature analysing the impact of airport investment on economic growth has been limited Among this limited volume of research, various objectives and methodologies have been posited. Almost all of airport impact studies apply the economic impact method as a means of analysis In general applications, the economic impact analysis focuses on explaining regional growth disparities (Armstrong and Taylor, 1985). The theory seeks to establish the economic determinants or variables causing regional business cycles. Airports have been considered as having a regional function for their economic influence The airport operations might affect economic activities of the city in which the airport is located The economic impact analysis is then essential for appraising a proposal for airline service expansion or airport development in a region Principally, there are three main models commonly used in the economic impact analyses of airport expansion the economic base models; econometric models, and input-output models

4.1 The Economic Base Model

The economic base model considers that a local economy is similar to a household having single source of income The income and welfare of the local economy will increase if the revenue of the single source of income improves The structure of household economic activities comprises only

two sectors: basic and non-basic sectors Export industry is the only source of income of the region and it becomes the basic sector for inducing other economic activities. The non-export industry becomes the non-basic sector which mainly serves the exporting industries and only spends its money within the region. The exporting firms sell their products to other regions The money inflow is then spent within the region increasing income and employment opportunities for other economic activities. The original spending inside the region are then transmitted and spread throughout local economy. This creates a multiplier effect which makes the economic activities yield final output that is greater than the original influx of money. Within this process, the leakage effects, such as import, savings and taxes, also occur. The flow-on spending will cease when total multiplier effects equal total leakage within local economy. The major weakness of the EBM in the economic impact analysis is its inability to explain the impact mechanism occurring amongst interrelated industries. The EBM produces only total economic impact in the entire economy In fact, this intertwined impact is essential to estimate the consequences owing to the marginal change of transport facility in each economic sector. Coupled with other conceptual weaknesses discussed by Jatmika (1999), the EBM is not recommended to be used as a means for estimating the economic effects of transport airport infrastructure, on regional development.

4.2 The Econometric Model

The econometric model is a quantitative economic model consisting an interrelated set of equations, which describe the economic structure of a region. The main focus of the model is to estimate the effects of changes in the pattern of expenditure on output, regional income and employment. The model also estimates directly the magnitude of multiplier effects of economic activities on a local economy.

The main framework of the econometric model utilise the general equation form of the Keynesian open model's structure:

$$Y = C + I + G + X - M \qquad (1)$$

Where

Y = economic output,

C = aggregate consumption;

I = investment;

G = government expenditure,

X = export, and

M = import

In general, this equation form is almost similar to that of the economic base model The difference lies in the structural relationship between equations Unlike the economic base model, the econometric model employs time series data to estimate the coefficients of independent variables Multiple regression technique is applied to calibrate the model which is therefore categorised as a location-specific model and associated parameters

Principally, the econometric model tries to calculate the economic activity linkages in a certain area, and between the area and other regions The econometric technique estimates the interrelation

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between elements of the system of equation Then the final model that is used for predicting the values of dependent variables, represents the mathematical formulation of the linkage between elements in the model, including the economic multiplier. The number of equation sets and formulations vary among the econometric models. For example, Benell's (1995) model has only two equations Availability of data and the purpose of study are important determinant of model specification.

In many instances, some of the econometric models mainly concern with exogenous variable affecting the regional growth or decline Thus, most econometric models focus only the demand side of the economy. These models also assume that price and wage are constant in the short-run and long-run. In general macroeconomics theory, the demand-oriented approach is the same as that of the Keynesian Income-Expenditure (KIE) model which emphasises the importance of capital, income, consumption, government expenditure, export and import as the operational variables in economic growth. In the KIE model, the role of transport-infrastructure is taken for granted It ignores the limitations of the supply side of the economy. In fact, inadequate transport-infrastructure might rise the price factor. This violates the model's assumption

To avoid this violation, other econometric models attempt to include both exogenous and endogenous variables, such as capital, labour, export and technology, as the determinant of economic development These models try to adapt the neo-classical framework giving emphasis on the supply side of the economy. Price and wage are set as variables In this framework, the role of transport-infrastructure is stated more clearly than that of the KIE model Factor movements influence the economic system stability. For example, labour and migration require transport services to move between places. Price and wage are allowed to fluctuate following the limitation of supply variables to stabilise the system's equilibrium However, the role of transport-infrastructure is still implicitly stated within this neo-classical theory.

The econometric model has been applied in practice to estimate the economic impact of airport services in the airport's vicinity The model given by Benell and Prentice (1995) is capable of providing detailed impacts of airport operation on local economic development, especially for Canadian airports Similar to the general econometric models, the main focus of the model is to predict the <u>direct effects</u> of changes in the pattern of expenditure on regional income and employment In the system of equation, all independent variables, such as passenger traffic, itinerant aircraft movements, community wealth and the existence of airport facilities, are in the right hand side and the dependent variables, such as direct revenue and employment, are in the left hand side. The final equations are as follows.

$$\ln E = -10.337 + 0.754 \ln P + 0.593 \ln W + 0.332 \ln B + u \qquad (2)$$
$$(-5.29) \quad (19.02) \qquad (3.05) \qquad (2.31)$$
$$\ln R = -0.821 + 0.493 \ln P + 0.937 \ln W + 0.178 \ln L + 0.482 \ln B + u \qquad (3)$$
$$(-0.29) \quad (4.47) \qquad (2.93) \qquad (2.43) \qquad (3.22)$$

in which

E   = person-years of direct airport-related employment

R   = annual revenue of airport service

P   = embarked and disembarked air passengers at the airport in 1988

W   = the relative wealth of city residents which is approximated by the average market price of houses sold that year

L   = the number of heavy plane movements (> 35,000 kg)

B   = 1 if airline has its maintenance base at the airport, 0 otherwise.

Benell and Prentice (1995) claim that their results are quite significant and robust. The R^2 values are greater than 0.95. It means that more that 95% of the variation of the means of both models can be explained by the above variables. The coefficients of the independent variables of both equations have the values between 0.3 and 0.9. They are statistically significant at the 0.05 level or better.

4.3 The Input Output Method

The economic impact analysis by using the Input-Output approach is not new. However, it is still becomes an important means to describe the economic structures of a region or nation The Input-Output Method is the most popular approach amongst the economic impact methods to analyse the effects of transport facility provision or expansion on economic development An outstanding feature of the Input-Output model is its capability of describing, analysing and predicting regional economic activity by using an input-output table showing the inter-industry activity linkages and flows of goods and services in the linkages Moreover, the model is also able to specify the total output for each industry which is needed to produce a certain level of final demand within a region

The Input-Output table plays the key role in the Input-Output analysis The row of the table shows the output that is produced by sectors in the economy. This will be used by other industries as intermediate and final uses. The columns of the table show primary and final inputs which are provided by other sectors or industries for production processes Horizontally, every table's entry denotes an output allocation Vertically, the entry becomes the input of sectors which are provided by other sectors

The mathematical expression of typical Input-Output structure is as follows (Pleeter, 1980):

$$\sum_{j=1}^{s} X_{ij} + \sum_{f=1}^{t} Y_{if} + e_i = X_i \quad - (i = 1,2,3,...,s) \qquad (4)$$

in which.

X_{ij} = output of sector I to sector j

Y_{if} = output of sector I to final demand sector f

e_i = export output of sector I

X_i = total output of sector I

s   = number of sectors

t   = number of final-uses sectors excluding export

The expression of the model can also be given in the form of input side

$$\sum_{i=1}^{s} X_{ij} + \sum_{p=1}^{t} V_{pj} + m_j = X_j \ldots \ldots \ldots (j = 1,2,3, .,s) \qquad (5)$$

where

X_j = total production in sector j

V_{pj} = value-added from sector p to sector j

m_j = imports by sector j

The Input-Output analysis has three main assumptions. the production function has constant coefficients; there is a linear relation between inputs, and external factors beyond the Input-Output system is ignored. On the basis of these assumptions, the coefficient of technology can be defined as follows

$$a_{ij} = \frac{X_{ij}}{X_j} \qquad (6)$$

Further mathematical elaboration, by using matrix expression, of equations 4 and 6 yield another form of Input-Output equation:

AX + Y + E = X

X(I - A)   = Y + E

X = (I - A)$^{-1}$(Y + E) = B (Y + E)   (7)

The element of B, that is b_{ij}, denotes all impacts, including direct and indirect effects, as the result of the sale from sector j to sector i for producing an extra unit of final demand. The income multiplier effect can be calculated by using the following equation

$$k_j = \sum_i b_{ij}.V_i \qquad (8)$$

with

k_j = income multiplier

V_i = value added per unit of output in sector I

The employment multiplier is computed by using the employment data in place of the value-added data in equation 8

Multiplier effects play an important role in the analysis of airport service impacts on the local economy In many airport impact studies, the economic impacts mean the generation process of local economic activities, job opportunities and payrolls as the result of direct and indirect operations of an airport The economic impact considers an airport as an industry since the airport provides employment opportunity and needs goods and services to support its activities. In principle, there are three types of impact. direct, indirect and induced effects The sum of these impacts constitutes the total impact of airport operation on economic growth

Direct impacts are economic activities which are conducted in the airport location by airline operators, airport authority and management, aviation-related companies and other tenants. In the absence of an airport, all of these economic activities will not occur These businesses provide jobs to local people, consume locally-produced goods and services, and pay taxes to local government The impacts of the expenditures of the business on the local economy are restricted by the local value-added component and regional-import component For example, the fuel purchase by the airlines requires local fuel storage and generates fuel importation and distribution However, Butler and Kiernan (1989, p 66) argue that only fuel expenditure is appropriate for the impact analysis This consideration also holds to the value-added analysis of expenditure of restaurants, retail shops that resale the imported goods to the customers

Indirect impacts are economic activities which are carried out entirely beyond the airport boundary These off-site activities include travel agencies, restaurants, accommodations, and retail stores. The indirect impacts are heavily dependent on the presence of an airport Without the existence of airport activities, business linkages between airport-related and non airport-associated businesses might not occur Tourism activity is intimately attributed to the indirect impact since they would not have come to the area if the airport facility is unavailable. However, it should not be overstated Other non-tourist visitors might come to the area by using other modes of transport. Therefore, the distinction between the number of tourists and other visitors need to be identified carefully

Induced impacts are changes in income and number of jobs created as the direct and indirect expenditures stimulate successive rounds of spending through the local economy The calculation of induced impact employs the concept of economic multiplier to the direct and indirect expenditures. The multiplier calculates the changes in total expenditures, in a certain region, for every monetary unit of initial spending.

The economic impacts of an airport operation are the total successive spending in goods and services commencing from the airport site to the rest of local economy through the transactions between industries and economic sectors in the hinterland. The final result is usually represented in the forms of monetary value of the total effects or in the forms of job creation which is based on the expenditure flows. Cranitch and Noud (1992) provide a good description of the economic impact of airport operations on a local economy (Figure 5). In essence, there are four kinds of impacts that airport operation can generate to local economy: revenue of companies, employment opportunity, individual earning and taxes (Cooper, 1990) Furthermore, the effects affect five main economic sectors airline and concessionaires, airport operator, air-cargo shipment, airport-related businesses, airport contractors and consultants, and airport-access transport. To predict the total impacts on these sectors, the model employs the income multipliers to the entire economy within the region
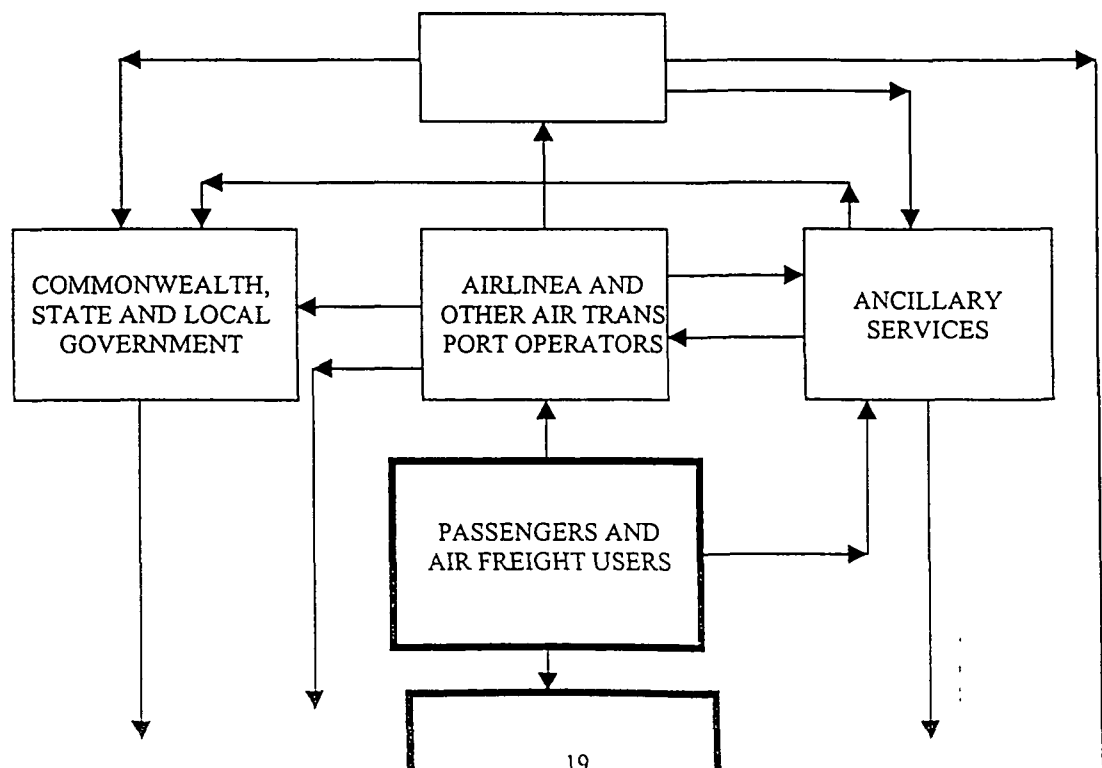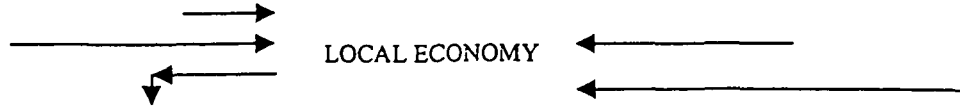
Source adapted from Cranitch and Noud (1992, pp 4-7)

Figure 5. A Model of Airport Activity and Local Economy Linkage

The input-output model has been extensively used in many studies to evaluate the extent of transport's role in inducing output growth. Bennathan and Johnson (1990) provide a good explanation on the role of the general transport sector as an operational variable in the Input-Output Method. This method applies all of economic factors as its operational variables. The result is quite promising. They claim that the Input-Output table can estimate the demand for transport industry as an input requirement for producing a certain amount of output. For example, Oh and Lee (1997) apply the Input-Output method which combined with the Network Effect Analysis to evaluate the economic impact of additional provision of highway network on South Korea's economy. They show that the method is quite good to estimate the positive economic impact of the proposed highway network on the national economy Morison (1991) employs the Input-Output method for estimating the multiplier impacts of Brisbane seaport. The multiplier value for employment is around 1.8. The application of this Input-Output model has some limitations In this case, Davis (1990) provides a good critique on the application of the Input-Output Model to estimate the economic multiplier effects of seaport to its hinterland.

The Input-Output Model has also been commonly employed to predict the economic impact of airport activities on local economies. For example, the US Department of Commerce's Bureau of Economic Analysis develops a specific input-output model for assessing economic impacts of airport provision which is called RIMS II (Regional Input-Output Modeling Systems) This model has been extensively used in various economic impact studies in the US airports. It can estimate, to certain levels of accuracy, the multiplier effects using a regional input-output table derived from the national input-output table In Australia, the application of Input-Output method also dominates the economic impact analysis for both major and minor airports throughout the country Included in these airports are Sydney International airport, Perth International airport and Townsville International airport (Hooper, 1995). Table 2 lists some examples of multiplier values that various types of transport facilities, including airports, can provide to its surrounding economies. The values of multiplier output for airports in these studies vary between 1.4 and 3 8 in the US, UK and Australia

Table 2. Multiplier Values of Various Types of Transport Infrastructure

Author	Country	Infrastructure	Multiplier Value (total)	Indicator Variable
Oh and Lee (1997)	South Korea	road	1 1	GNP
Obermauer (1997)	Japan (Kyushu and Tohoku)	high speed train	0 376 to 2 78	employment
Evers et al (1987)	Netherland	high speed train	0 002	employment
Morison (1991)	Australia	Brisbane port	1 8	employment
Robertson (1996)	UK	airport	3 8	employment
Jarvis et al (1976)	US	airport	2 2	employment

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Hutcheson (1996)	UK	East Midlands airport (UK)	1 4	employment
Kinhill (1990)	Australia	Sydney airport	1 99 2.03	employment output
National Centre for Studies in Travel and Tourism (1990)	Australia	Townsville airport	3.7 2.9	employment income
ITS (1997)	Australia	Sydney airport	1.99 2 03	employment output

Recent work by the Institute of Transport Studies or ITS (1997) investigates the economic impacts of Sydney airport on its surrounding economies using the Input-Output Model. The type of industries and services having direct impact of airport operations includes international and major domestic airlines, general aviation, charter airline, commuter airline, airport administration, commerce, air freight forwarders and custom agents, transport companies serving passengers to and from airport, and accommodation in the surrounding areas of airport It is estimated that approximately 33,509 jobs can be created by the airport activities. By applying the multiplier value of 1.99 found by Kinhill (1990), the airport can offer almost 66,590 directly and indirectly to airport related jobs which accounts for almost 8% of Sydney's total workforce Total direct expenditures of the airport-associated industry are estimated around $3,855 million. Meanwhile, total direct and indirect expenditure impacts in Sydney region is around $7,807 million

Compared with the first two methods, the Input-Output model can provide more accurate results. It can explain analytically the inter-industry transactions or linkage within an area Moreover, the Input-Output model employs more economic variables than other economic impact models The summary of the operational variables in various regional economic models is shown in Table 3. This table further describes that all theories always contain export as one of the operational variables determining regional economic growth This reflects that export is an essential economic factor to be promoted in order an area to have a significant output growth. The other important operational variables are income, capital, import, labour and technology Consumption and Government expenditure are considered as a determinant for economic development only by two theories: the KIE and Input-Output models. It is clear from Table 3 that the Input-Output model is the only model employing all economic sectors as its operational variables

Table 3. Operational Variables in Various Regional Economic Theories

THEORY (MODEL)	Capital	Labour	Income	Consumption	Export	Import	Gov't. Expenditure	Technology
Export-based			v		v			
KIE Model	v		v	v	v	v	v	
Input-Output	v	v	v	v	v	v	v	v
Neoclassical	v	v			v			v
Export-led	v	v	v		v			v
International Trade					v	v		

Source adapted from Armstrong and Taylor (1985)

5. Environmental Impacts of Airport on Land Use Change

That airport brings advantages to travelers, business and commercial sectors have been widely acknowledged. However, as with other means of transport, major airports generally cause social and environmental impacts to its surroundings In the context of environmental effects, airports have the potential to downgrade the air and water quality, to endanger the life of specific flora and fauna, to generate traffic congestion in the access road to and from the airport, to cause severe visual obstruction and community severance, and to bring about aircraft noise disturbance to the adjoining people. The profound socio-environmental effects that a major airport has on its vicinity are the urbanisation process itself and aircraft noise impacts. These impacts may affect the life style, structure and activities of the people living inside and outside the airport area The effects have far-reaching implications in the sense that urbanisation and noise issues might have spatial and political dimensions. Both urbanisation and aural pollution effects will be the main discussion in the next sub-section

5.1 Urbanisation Process Stimulation: A Theoretical Framework

Major commercial airports have long been considered as being large business enterprises which require a considerable amount of land. In the past, many of the present major airports were built in the outskirts of the city At that time, the air traffic volumes were still very small and the aircraft needed only short runways. Accordingly, there was no serious land use problems, such as land acquisition and people displacement in the past

The land use issues began to emerge when the city continue to grow, the introduction of jet aircraft into commercial services and the increasing demand for air transportation in major airports. As one of the nodes within air transportation network and as an interface between air transportation and other modes of transportation, major airports need a great deal of land to support its operations, such as for catering many inbound and outbound aircraft, cargo and passenger movements The increasing air traffic demand would require further airport development. This might include runway expansion, passenger amenity extension and cargo handling development which further needs airport's area extension beyond its former boundary, as long as the land supply is still available

This soaring demand for air traffic needs to be balanced not only by the development of ground facilities in the airport area, but also by the extensive improvement of access roads connecting the airport with the nearby city and other regional centres The roads are very essential to expedite the movements of passengers and airfreights to and from the airport The development of access roads often passes through the formerly undeveloped regions In this sense, the roads will improve the accessibility and therefore increase the development potential of the untapped areas

Other utilities supporting the development and operation of major airport, such as sewerage, water, gas, electricity and telephone, can be used not only for servicing the airport needs but also for other purposes in the neighbouring areas The special investment in these utilities would help reduce the public capital expenditures that would otherwise be incurred if these supporting facilities were not already provided

The development of access roads, along with other utilities through the relatively undeveloped area, enables people from the dense areas to move to the new areas nearby the airport These areas have relatively cheap price and have the sufficient provision of public utilities As the urbanisation

pressure increases on account of increasing city population, many people will tend to move in the new areas in the city outskirts towards the airport site The newly developed areas will further create new business and employment opportunities as well as residential areas development It can be concluded that airport development is capable of stimulating urbanisation process, redistributing city population especially along the access road corridors, and supporting urban agglomeration The latter aspect needs further discussion.

As stated previously, major airports tend to need a great deal of land. Besides the airport, other airport-oriented firms also require certain amount of land in the surrounding areas to run their businesses. According to Hoare (1971) only a certain type of corporation considers airport as its decision variable for locating their business Generally, only tertiary industries put the airport as the primary aspect in their location decisions The first reason is that companies having overseas-oriented markets and offices regards that places near airport can provide greater access to air travel for their staffs and patronage. Secondly, the firms feel that being close to airport might increase their prestige

Sealy (1976) argues that there four kinds of industries having strong association with airport activities transport-related industries having domestic and overseas markets, such as electronic companies and transportation equipment, industries having regional market in the metropolitan area, research and development industries, and accommodation and ground transportation industries

Major commercial airports are able to provide a large number of employment opportunities in which many households are dependent on these jobs The employment attractiveness and relatively cheap housing prices would further induce the urbanisation process on the adjacent areas of the airport. This theoretical framework of urbanisation process mainly occurs in less developed areas such as in the outskirts of the city In the built-up areas, the process might not happen entirely. Rezoning or change in land use function is very likely to occur The later process, and some improvements of access roads, will be discussed in this paper by using a case study of Sydney Kingsford Smith Airport (KSA)

5.2 The Impacts of Sydney KSA Operations on Land Use Development of its Surroundings

Major airport operations and development might have some possible effects on the use of land in its surrounding areas as a consequence of the increasing air traffic volumes and economic activities there The previous sections deal with the potential and magnitude of economic benefits that airport can create to its vicinity but without considering the Spatial details. This section attempts to identify the locations of some of the effected industries and the manifestation of the land use pattern changes owing to airport development and operations in the surrounding areas of the airport. For the study purposes, a part of the Industrial Special-Airport Related Zone in the north of airport site, especially a specific area in Chalmers Crescent, a part of Kent Street and King Street, is selected as a case study area This area will be used for the investigation of land use pattern changes due to airport operations and development since 1971 Symons (1971) started to document the pattern of land use in the study area and this research extends his study and other research undertaken by UNSW Department of Transport Engineering to identify the land use function changes over 28 years period

5.2.1 Areas in the Surrounds of Sydney KSA

Sydney KSA is located on the northern shore of Botany Bay and is surrounded by four municipalities (Figure 6). The airport is bounded to the east by Botany municipality, to the north by South Sydney municipality, to the west by Rockdale and part of Canterbury municipalities. The north-south parallel runways extend the aerodrome to the south into Botany Bay. Five distinct local communities can be identified each, having different land uses and resident populations. Tempe-Sydenham area, Arncliffe-Kyeemagh area, Mascot Industrial Area, Mascot Residential Area, and the Botany suburb (Figure 7).
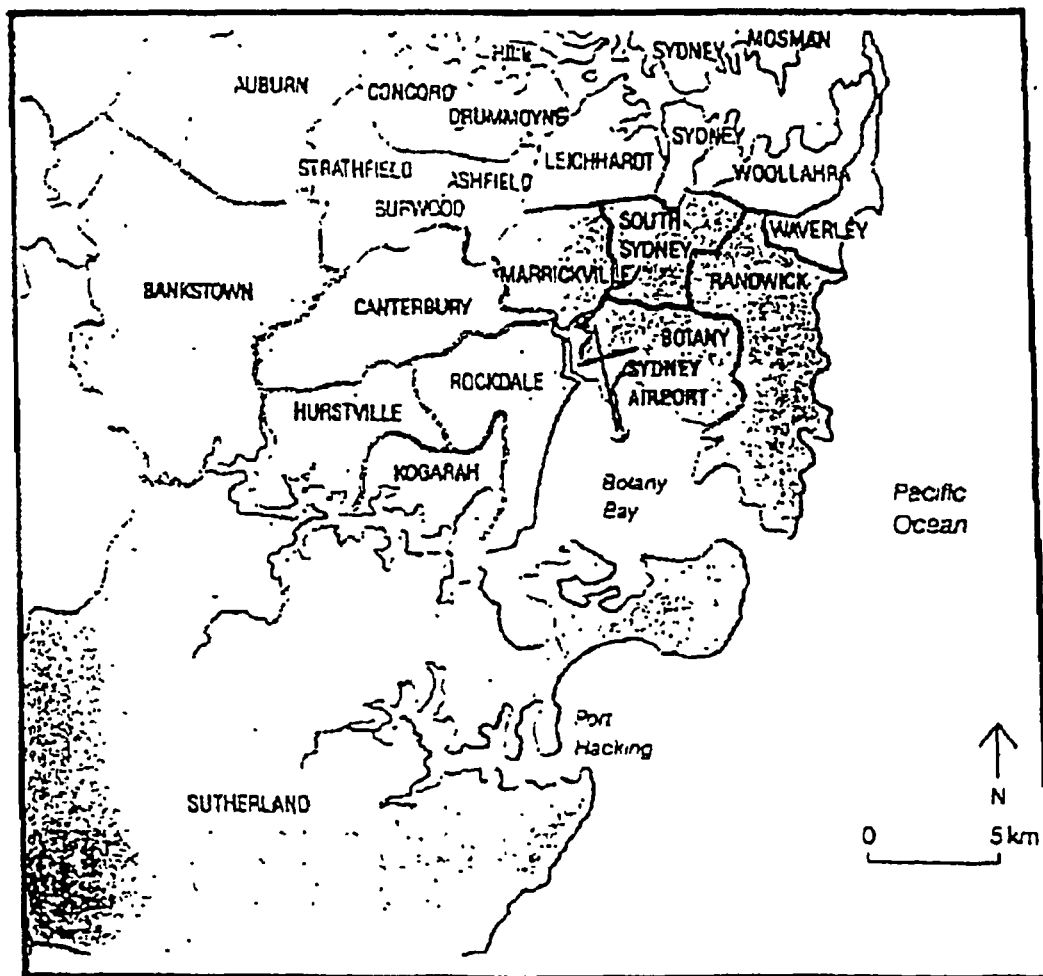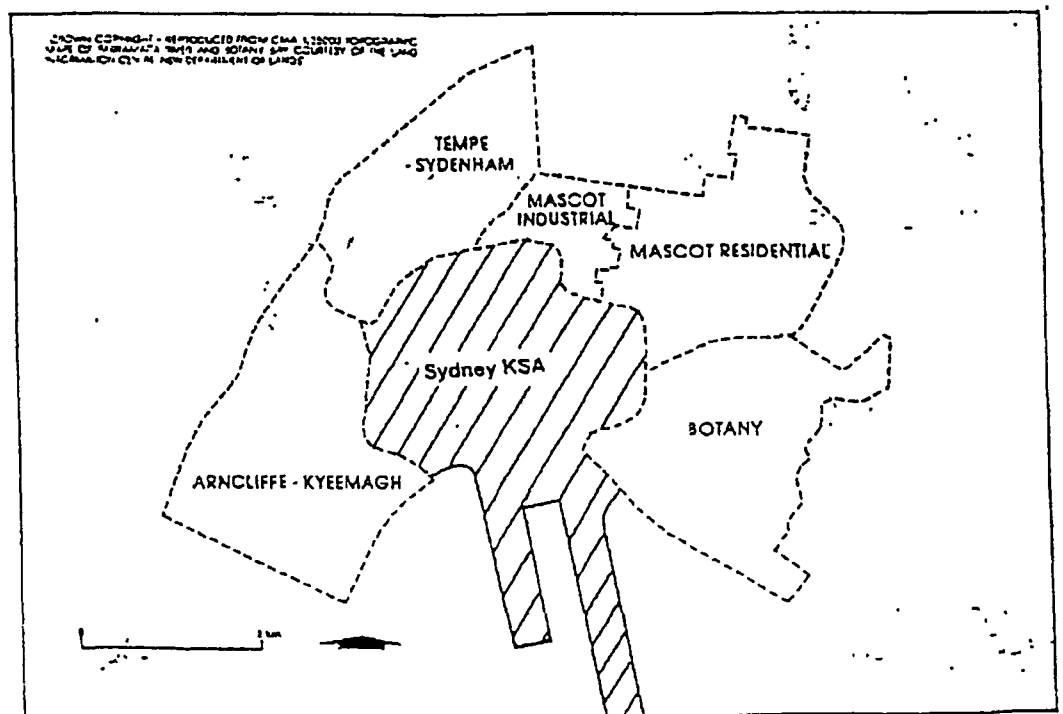

Source Kinhill (1990)

Figure 6 Areas in the Environs of Sydney Kingsford Smith Airport

Tempe-Sydenham area is located in the north of Sydney KSA beside the Princess Highway It is bounded by railway line to the west and by Alexandria Canal to the east Between the highway and the railway line, most of the land uses consist of mixed residential and industrial areas, while between the highway and the canal, there are rail good yards, warehouses and container storage. Abutting the southern part of this area to the airport itself is partly recreational area and partly vacant land.

Kyeemagh-Arncliffe is located to the west of the airport across the Cooks River. Residential and open space areas dominate land uses in this area. In the Arncliffe area, between Rockdale and Canterbury municipalities, some parcels of land are used for industry. These areas are located near the Princess Highway linking north and south Sydney

The land use pattern in the Botany suburb is characterised by an equal mixture of residential and industrial areas. The industrial area mainly relate to processing and storage of petroleum, chemical and petrochemical products. These areas also have community facilities and commercial areas which are mainly located in Pagewood and along Botany road. Land use rezoning also took place in this area. Some previous industrial area near William Street has been converted into housing area (Coupe, 1998).

Mascot residential area is dominated by housing that is supported by community centres and associated commercial areas serving the people and the surrounding workforce This area has little space for further residential development Some of the areas are occupied by airport-related businesses such as Qantas and Cathay Pacific Catering Services.

Source Kinhill (1990)

Figure 7 Local Communities in the Surrounding Areas of Sydney Kingsford Smith Airport

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The Mascot Industrial area is located in the north of airport between the Tempe-Sydenham area and Mascot residential area. In 1987, this area has been rezoned for airport-associated activities. As a result, many land uses are mainly occupied by air cargo shippers and airline-related activities, such as offices and accommodations (Kinhill, 1990).

5.2.2 Land Use Pattern and Function Changes in the Airport's Vicinity

As stated previously, generally there two distinct effects that airport development has on land use changes in transport arrangement access and alterations in land use patterns or functions. Major factors, such as market forces, urban development trend and control, and special characteristics of the local areas, influence the changes in land use pattern including the provision of new access roads. This study will focus only on the manifestation of airport operation and economic activity effects on the surrounding areas of Sydney KSA. Tables 4 to 6 list the historical alteration of land use patterns in and around Sydney KSA which shapes the arrangement of present land use following the establishment of the aerodrome there in 1919. The evaluation of access road historical development will be explained in the wider areas while the evaluation of changes in land use pattern will focus on the specific study area.

5.2.2.1 Access Road and Transport Development

The first development of access major roads was the construction of General Holmes Drive replacing Lords Road in the 1950s. Massive developments of access road were conducted in the 1960s when Qantas drive was built in 1964 It provided access to domestic and international terminals situated in the northern part of the airport. Moreover, this road also links Botany municipality and Rockdale municipality During this period, General Holmes Drive was improved and a new tunnel under the north-south runway was constructed. Moreover, Foreshore road was also built along the beach in the eastern part on Botany Bay. These roads enhance the accessibility of Sydney KSA from south Sydney The new construction of a bridge across the Cooks River improved the northern access way to Sydney KSA significantly.

Table 4. Sydney Kingsford Smith Airport Development and Associated Changes in Land Use Patterns in its Vicinity Between 1919 and 1944

Year	Major Facilities and Land Use Alteration
1919	Mascot was chosen by the Australian Aircraft and Engineering (AA&E) Company as the site for the first aerodrome and aircraft factory in Australia
1921	Federal Government assumed control of Mascot airport The Civil Aviation Authority controlled the aerodrome of Mascot airport under Air Navigation Act 1920
1927	Workshop, clubhouse, and Department of Civil Aviation offices were built Hangars and groundsman housing were also established.
1930	Housing acquisition in the Lauriston Park community (8 houses)
13/05/30	Gravel runway was constructed along with two other runways for emergency purposes
1938	Terminal building was built and Department of Civil Aviation was established
1940	Reception areas and control tower were inaugurated Terminal buildings were completed for the Australian National Airways and Airlines of Australia
1941	Sealed runway was constructed along with bricked administration building (executive staff, meteorological and wireless section)
1943-1944	• Runways and landing areas were extended • The main runway was expanded up to 1463 metres • More lands were acquired in northeastern section for other runway extensions

Source Gall (1986), Kinhill (1990), Black (1996)

Table 5. Sydney Kingsford Smith Airport Development and Associated Changes in Land Use Patterns from the Beginning of the Internationalisation Era (1945) to the Beginning of the Jet Age (1958).

Year	Major Facilities and Land Use Alteration
1945	Sydney KSA was developed as an international airport following the Bradfield Master Plan.
1947	• The first international flight (Panam) came to Australia
	• The government acquired the North Brighton Golf Links, a cricket ground, a Water Board's strip of land, the Kyeemagh Polo ground, the NSW Gun Club, the Bonnie Dune Golf Links
	• The government also purchased the remainder of the Wimble Ink factory and the Mascot Granite Works
1950-1955	• (Two-Airline Policy was enacted incl. Trans Australia Airlines and Australian National Airways in 1952)
	• (Civil Aviation Agreement Act was passed by the parliament).
	• Construction of main East-West runway and North-South runway.
	• The Cooks River was diverted to its present course
	• The elimination of the golf courses and Ascot Racecourse
	• The elimination of Lords road and its replacement with General Holmes Drive
	• The enlargement of the airport site from 10 hectares to 330 hectares
	• The first runway operation was commenced (1952)
	• Qantas' engine testing house was built (1955)
1956	The improvement of catering facilities and a landing system instrument was installed
1958	Control tower was improved and extended

Source Gall (1986), Kinhill (1990), Black (1996)

During the 1970s and the 1980s, there were no major access road development occurred. As the air traffic volumes and economic growth continue to increase in the 1980s and the 1990s, the airport activities also increase significantly Such tremendous increase in airport operation was not balanced by the improvement of access roads Consequently, road congestion along the Qantas Drive and several major roads, especially during inbound international flight arrivals in the morning, had become a serious issue. It is predicted that, despite the recent Asian economic crisis, the air traffic volumes in Sydney will continue to increase in the future Furthermore, the Sydney 2000 Olympics Games, in part, is also expected to contribute to the growth of air travel to and from Australia through Sydney KSA To address this problem, the NSW State Government is now constructing a new railway line in a tunnel linking Sydney KSA and Central Railway Station in the CBD area via Mascot industrial area (Scott and Black, 1998) This project will be completed in 2000. It is expected that a great number of air passengers will use this new service and hence reduce the traffic volumes on the existing access roads. The new railway line will also help to strengthen the functional and strategic links between the Sydney CBD and the Sydney KSA Other important access road development is the construction of the Eastern Distributor and M5 East Highways through Sydney KSA (Coupe, 1998) These roads will also help to reduce congestion in the major urban roads heading to the airport and they will be completed in 2001 Thus, doing the postwar period, transport land uses have changed substantially

5.2.2.2 Changes in land Use Pattern in the Airport's Vicinity

The land use development and changes at Sydney KSA began in 1919. Before the Second World War, land use development and expansion were not significant Major development occurred during the World War Two when the runways were extended and sealed. In this period, the Australian Commonwealth Government built terminal buildings, passenger amenities and air traffic control facilities Large airport expansions to areas beyond its boundary started in 1945 when Sydney KSA was developed as an international airport following the Bradfield Master Plan of 1947 A great deal of lands in the surrounding areas, such as the North Brighton Golf Links, a cricket ground, a Water

Board's strip of land, the Kyeemagh Polo ground, the NSW Gun Club, the Bonnie Dune Golf Links, the remainder of the Wimble Ink factory and the Mascot Granite Works, were acquired by the government.

Table 6. Sydney Kingsford Smith Airport Development and Associated Changes in Land Use Patterns in the Jet Age (1959-1999).

Year	Major Facilities and Land Use Alteration
1959	• The beginning of the jet age in Australia by introduction of Boeing 707. • Expansions of access roads to terminal buildings • Northwards extension by diverting of the "Botany Good Lines" and acquiring 4 streets. • Noise and water-vapour pollution complaints started along with fear of airplane crashes.
1960	Qantas jet base was built by displacing two light industries in the northeast corner
1961	Railway line was relocated by displacing 2 hectares of light industrial development (this added another 14 hectares of land to the airport)
1963	The north-south runway was extended A part of Botany bay was reclaimed
1964	Provision of Qantas Drive and 3 streets (for serving Qantas maintenance base)
1965-1968	• Part of Botany bay was reclaimed and the extension of north-south runway to the south. • Construction of General Holmes Drive tunnel under the runway
1968	• The development of a new custom house, apron extensions, eastern hangar area, power house for lighting the north-south runway (by TAA) were completed. • Qantas built an administration building, cargo building and avionics laboratory • Ansett constructed cargo buildings
1969	• Draining of lakes, provision of international terminal and access roads through Qantas Drive, Establishment of Air Traffic and Communication Centre • Runway extension further south into Botany Bay commenced • Qantas built a new flight kitchen, a multi-story car park, a hangar for Boeing 747, a jet engine test cell, a simulator building, some repairs and overhaul shops, a central store, a central plant building and concrete aprons
1970	Domestic and International terminal buildings started to operate
1972	• A new operation and control building was built • Access way improvement by constructing a new bridge across the Cook river
1973	The extension of the north-south runway was completed to accommodate jumbo jets
1975	Ansett and TAA redeveloped their terminals
1978	A new international apron was provided
1980	Sydney KSA approached its saturation point (around 180,000 aircraft movements per year)
1987	• Additional taxiways were completed. • The introduction of the Industrial Special-Airport Related Zone for airport related uses in Mascot
1992	Third parallel runway construction into Botany Bay
1994	• The third parallel runway was commissioned • International terminal extension
1995 - 2000	The construction of New Southern Railway Line
1996	New air traffic control tower
1996 - 2001	• Construction of Eastern Distributor • Construction of M5 East

Source Gall (1986), Kinhill (1990), Black (1996), Coupe (1998)

During the 1950s, Sydney KSA experienced significant changes in land use pattern and expansion The airport was expanded from 10 hectares to 330 hectares In this period, the Cook River was diverted to its present course to provide more land on the western side of the aerodrome Moreover, the east-west and north-south runways were established by eliminating golf courses and the Ascot Racecourse, diverting the "Botany Goods Line" further north and acquiring four more streets These runways replaced the old runway configuration in the Bradfield Master Plan Meanwhile, Qantas started to build its engine testing house and catering facilities within the airport boundary

The jet age commenced in the early 1960s by the introduction of the Boeing 707 into air transport services In this decade, another 14 hectares of neighbouring lands were acquired due to the relocation of the railway line Qantas and other major domestic airlines undertook major

infrastructure development, such as air traffic and cargo handling facilities, terminal buildings and passenger amenities, within and in the precincts of the airport

During the 1970s, the north-south runway expansion to the south was achieved by reclaiming part of Botany Bay Some airport facilities redevelopment occurred in this decade Further land acquisition to the adjoining areas became impossible due to space limitation and environmental consideration. On account of the latter aspect, there was no major change in land use patterns in the 1980s in the airport's vicinity. To cater for the growing demand for land use from airport-related services, while minimising the possibility of the acquisition of non airport-associated land use, the State government established an Industrial Special-Airport Related Zone in Mascot in 1987. This area is intended only to accommodate further demand for land use from airport-associated industries requiring proximity and access to both Sydney CBD and Sydney KSA.

Third parallel runway was the only major development altering the land use shape of the airport in the 1990s It was built on the eastern side of the existing north-south runway by reclaiming another part of Botany Bay. The land use functions within the airport boundary continued to change. The development was dominated by the extension of existing passenger terminals, parking facilities, airfreight facilities and split, two-level access roads

Land use development or rezoning in the airport's vicinity has been tightly controlled by State and Local Governments For example, the Botany Local Council through the Botany Business Enterprise Centre has controlled the commercial development in Botany municipality (Mr. Eardley, pers comm , 1999). The catering businesses supporting airport activities have become the major business there. These businesses are mainly located along Botany road and Robey Street and accounts for almost 26% of all business with the annual growth of 11%. The Local government attempts to maintain the constant annual growth by limiting its approval for the new catering business applications to achieve a sustainable economic development of the area Most of the land uses for industrial purposes have been used by transport-associated services and catering businesses. Meanwhile, the old and traditional manufacturing companies, such as Oracle and Eveready factories, have closed down

5.2.2.3 Changes in Land Use Function in the Study Area

Having dealt with the broad changes in land use arrangement at Sydney KSA and its vicinity in a temporal and spatial context, the research goes to the next level of spatial resolution and attempts to identify the evolution of land use patterns or functions in a smaller study area (Figure 8) Within the study area, there are 28 parcels of land occupied by various types of industry as listed in Table 7

The table identifies each of the 28 parcels of land, gives the street and address, the name of the firm and its broad economic activity Four periods of time are shown in the table to illustrate temporal changes in economic function in 1971, 1991, 1995, 1995 and April of 1999 Furhter analyses of these changes are currently underway, so we provide here only a brief interpretation of the details in Table 7
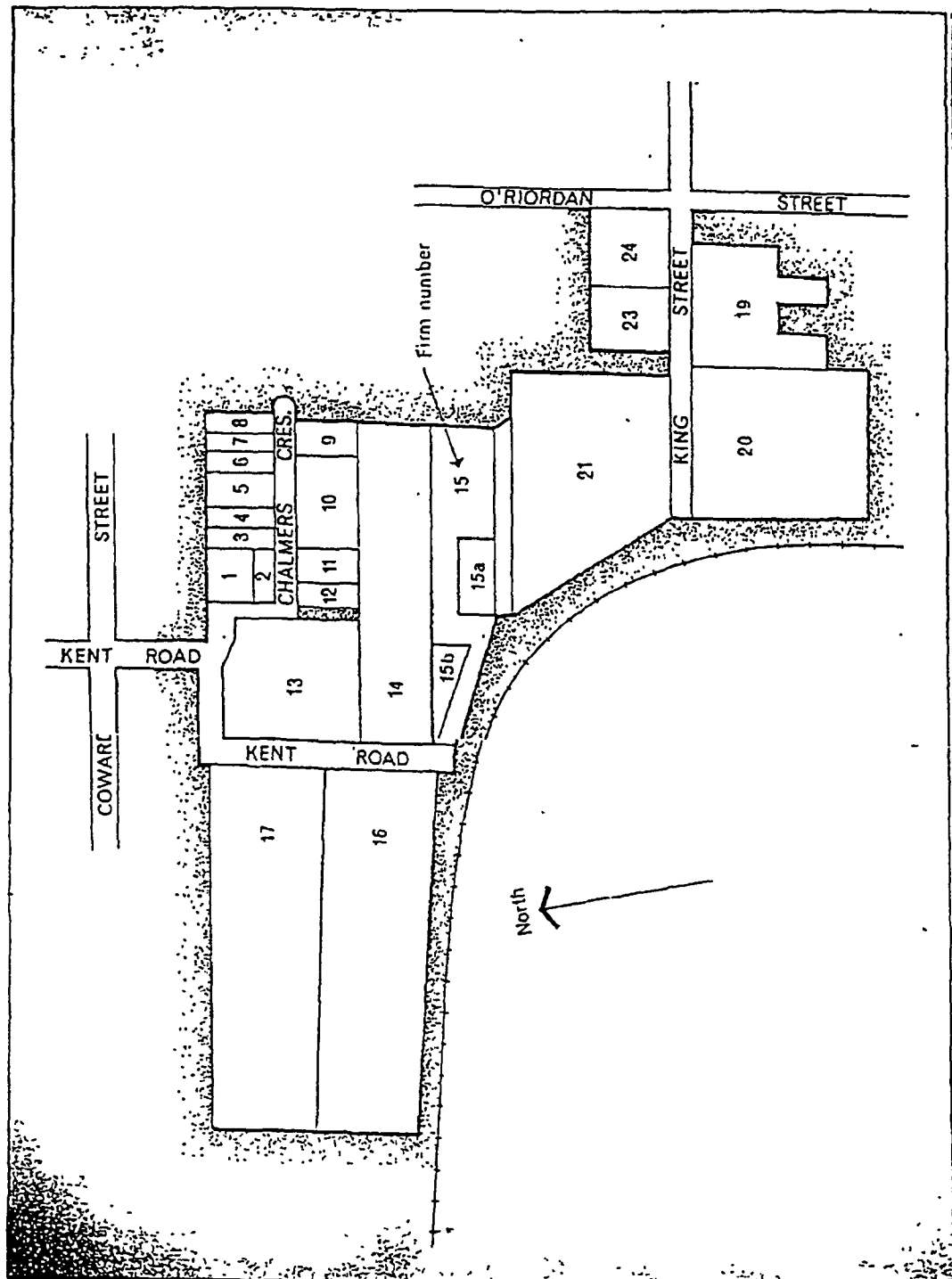
Source Symons (1971)

Figure 8 A Map of the Study Area (unscaled)

TABLE 7 Land Use Pattern Changes at Part of Mascot Industrial Area (Kent Road, Chalmers Cresent and King Street) Between 1971 and 1999

No	Address	1971 Firm	Activity	1991 Firm	Activity	1995 (June) Firm	Activity	1999 (April) Firm	Activity
1	2 Chalmers Cr	Alexander McGrath	Carrier	JMJ Fleet Management		Trade Facilitators	Customs, Freight	Connor Anderson	Custom, Freight
2	4 Chalmers Cr	Ingster Holdings	Lamination	Ingster Holdings	Lamination	Ingster Holdings	Lamination	Ingster Holdings	Lamination
3	6 Chalmers Cr	N Pine & Co	Carrier	Natural Gas		Natural Gas	Natural Gas	Natural Gas	
4	8 Chalmers Cr	Goldstein	Refrigeration	Geneva Furniture		Geneva Furniture		Closed Down	
5	10 Chalmers Cr	William Jacks & Co	Handling equip	Glasser		Romke Industry	Customs	Romke Industry	Customs
				Pacific Netwok Cargo		Carlton Customs Ag	Customs	Carlton Customs Agency	Customs
						NMS Smash Repair		NMS Smash Repar	
								Vacant	none
6	12 Chalmers Cr	May and Blake	Repairer	Closed Down		Central H I T S	Hotel, Club Supply	Central H I T S	Hotel, Club Supplies
7	14 Chalmers Cr	National Saw Works	Manufacturer	National Saw Works	Manufacturer	National Saw Works	Manufacturer	National Saw Works	Manufacturer
8	16 Chalmers Cr	Seeds Pty Ltd	Seed Merchant	Trans Asia Trading		Trans Asia Trading		Closed Down	none
9	18 Chalmers Cr	undeveloped	none	Angus Intern Freight		F Mayer Imports	Food Importer	F Mayer Imports	Food Importer
				Asean Cargo Service		F Mayer Imports	Food Importer	F Mayer Imports	Food Importer
				City Link		F Mayer Imports	Food Importer	F Mayer Imports	Food Importer
				Pike Speed		F Mayer Imports	Food Importer	F Mayer Imports	Food Importer
				F Mayer Imports		F Mayer Imports	Food Importer	F Mayer Imports	Food Importer
10	20 Chalmers Cr	undeveloped	none	Bow Port Pty Ltd	none	F Mayer Imports	Food Importer	F Mayer Imports	Food Importer
11	9 Chalmers Cr	Eric Wise Pty Ltd	Car part	Eric Wise Pty Ltd	Car part	Eric Wise Pty Ltd	Automotive part	Mascot Concrete	
12	7 Chalmers Cr	John Deere Ltd	tractors supply	Closed Down	none	Qantas Stores	Warehouse	Qantas Store	Warehouse
13	5 Chalmers Cr	Brookes Foods Ltd	Food Process	Closed Down	none	Brookes Foods Ltd	Food Processing	Brookes Foods Ltd	Food Processing
14	3 Chalmers Cr	I J Worsley Ltd	Food Supply	Estia Products		Estia Products		Estia Products	
15	1 Chalmers Cr	undeveloped	none	Closed Down	none	Closed Down	none	Aviation Distributors	Closed Down
16	55 Kent road	Brolite Pty Ltd	Paint Manuf	Atomic Scaffolding		Airborne Express	Carrier	Airborne Express	Carrier
		P M G	Cable Store	Brambles Int'l Freight				Vacant	none
		Mechanical Assembly	General Eng					Jupiter Air Oceania	Carrier
		H E Wildwater	Oil Ref Eng					Corporate Express	Carrier
								Legend Marine Service	Carrier
17	60 Kent road	undeveloped	none	undeveloped	none	undeveloped	none	Elephant's Foot	Garbage Compactor
18	62 Kent road	Dept of Army	Mec Workshop	Sydney Workshop Co		Sydney Workshop Co		Sydney Workshop Co	
19	64 Kent road	Joy Manuf Ltd	Mining Equip	Sydney Workshop Co		Sydney Workshop Co		Sydney Workshop Co	
20	285 King St	Allan Royle Drilling	Drilling Engineer	Power House		Power House	Customs, Freight	Power House	Customs, Freight
21	287 King St	Healing Appliances	Service & Adm	Universal Smash Rep		Universal Smash Rep		Universal Smash Rep	
22	289 King St	ACI Raw Materials	Sand Storage	Industrial Sugar Mill		Industrial Sugar Mill		Industrial Sugar Mill	
23	291 King St	ACI Raw Materials	Sand Storage	Industrial Sugar Mill		Industrial Sugar Mill		Industrial Sugar Mill	
24	293 King St	ACI Raw Materials	Sand Storage	Industrial Sugar Mill		Industrial Sugar Mill		Industrial Sugar Mill	
25	295 King St	ACI Raw Materials	Sand Storage	ADP		ADP		ADP	
26	King-Kent St	undeveloped	none	Qantas Catering	Airline	Qantas Catering	Airline	Qantas Catering	Airline
				Qantas Jet Base	Airline	Qantas Jet Base	Airline	Qantas Jet Base	Airline
27	342 King St	Mascot Galv Works	Galvanising	Mascot Galv Works	Galvanising	Mascot Galv Works	Galvanising	Mascot Galv Works	Galvanising
28	364 King St	J Murray More Ltd	Steel Merchant	Closed Down	none	Philip Upman P/L	Cargo	Sydmane	Removal,Storage

Source Field Survey (1991, 1995, 1999), Symons (1971)

The land use pattern of these parcels of land has been relatively stable since 1971. The function of the land use, however, altered substantially between 1971 and 1991. In 1971, non airport-associated industries dominated the study area There were only two of the industries that related to airport activity - carrier companies Since 1991, this area has been dominated by airport-related industries, such as freight forwarders, customs agency, food importer and processing, warehouse and airline activities, which account for almost 70% of the land use activities there. Recent field surveys in 1995 and 1999 showed that the percentage of the airport-related industries has been stable at 70% of the total activities. Table 7 further reveals that despite the stable percentage of airport-related activities, the business turnover has been quite high. This turnover, however, occurs only to businesses relating to airport-associated services The investigation of the land use pattern changes in the study area shows that land use control policy and market power from air transport services can affect, in part, the future pattern and function of land uses in the adjoining areas of a major airport. In this area, the land pattern changes is relatively slow but the business turnover is relatively fast. The next phase of the research aims to examine these changing business in more depth

6. Conclusions

Research in progress into the social impacts of airports has lead to the formulation of a conceptual framework that includes both positive and negative effects of airport development. The ultimate aim of this research is to provide airport management with a corporate communication approach, including an environmental management system that will allow it to deal more effectively with stakeholders and other publics, especially in the surrounds of major airports. This environmental management system will be designed to explicitly recognise the conflicts inherent in airport development - both economic and environmental (Nero and Black, 1998)

This paper has reported on that part of the wider research dealing with the indirect economic benefits of airport development To do this, we have reviewed the general literature on the role of transport in regional economic development and the more specific literature (which is more limited) on the role of airports and economic development. Governmental legislation in most countries requires an environmental impact assessment of infrastructure proposals In the case of airport expansion, the direct and indirect economic impacts are an important component of the overall appraisal process Our review of the methodology underpinning such analyses of indirect economic benefits shows the importance of the multiplier in forecasting such impacts A range of multiplier values for airports and other transport infrastructure have been presented here to give guidance of the possible magnitude of job creation, for example

Our argument in this paper is that such approaches in practice rarely consider the spatial nor the temporal dimensions of these impacts We do not have a firm understanding of the locational aspects of economic growth associated with airports Answers to these kinds of questions are part of on-going research using Sydney Kingsford Smith Airport as a case study Secondary data on land use change associated with the expansion of the airport from its original site at Mascot in 1919 is available and our own research draws on primary field work data collected over a 30-year period In this way

we have been able to establish the details of land use change and specific changes in industries and shown how airport-related activities have grown in the late 1980s and 1990s

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